

Volume II

Figures

COLOR in Black and White:
An Investigation of Vividness
in Color and in Architecture.

by

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1996

The outward and
inward Senses.*Sensus externi
& interni.*

There are five
outward Senses ;
The Eye 1.
seeth colours,
what is white or black,
green or blew,
red or yellow.

The Ear 2.
beareth Sounds,
both natural,
Voices and Tones ;
and artificial,
musical Tunes.

*Sensus externi
sunt quinque ;*
Oculus 1.
videt Colores,
quid album vel atrum;
viride vel cœruleum,
rubrum aut luteum, sit.

Auris 2.
audit Sonos,
tum naturales,
Voces & Verbi ;
tum artificiales,
Tonos Musicos.

The

Fig.1. A page from a Latin grammar compiled by a well-known English Renaissance composer of emblems, John Amos Comenius. It shows the brain as a sense organ.



Fig.2. Aristotle is pictured on the left, on the title page of Galileo's Dialogue (1632). Ptolemy appears in the center. The figure on the right is supposed to be Copernicus who is, in fact, represented in the guise of Galileo.

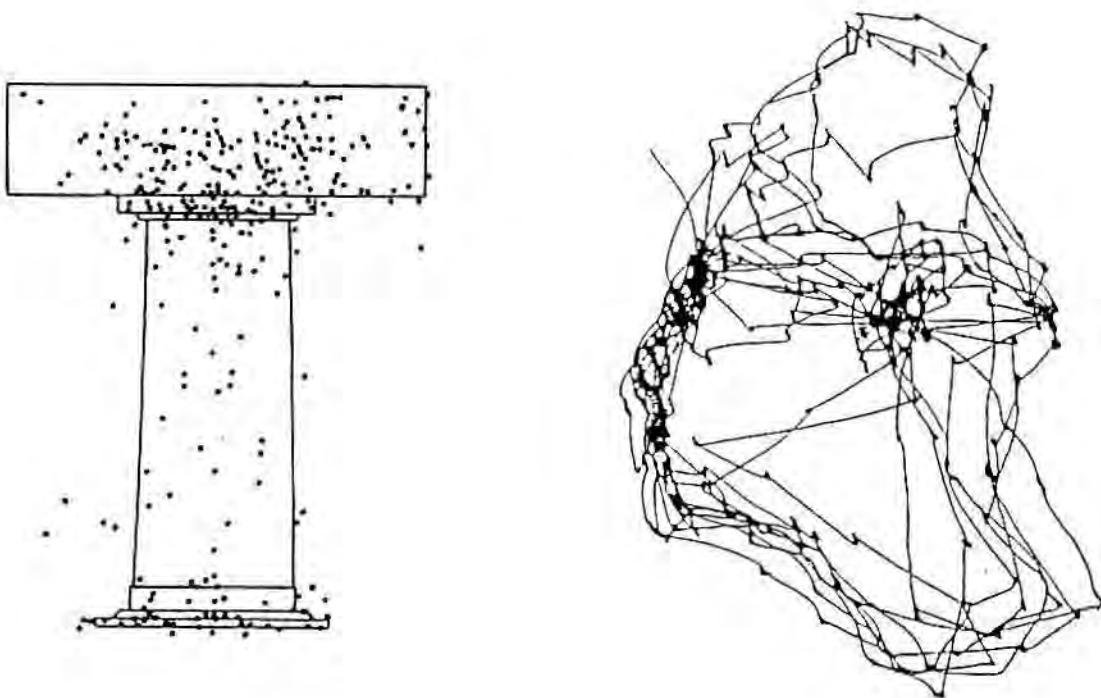


Fig. 3. Two different studies of visual fixation, on the left fixations are treated as discrete points. On the right fixations are shown as a dynamic process that in effect reconstruct the profile of a face, not from shadows given in the visual array, but from the movement of the observer's eyes.



Fig. 4. Alberti's personal emblem was a winged eye. Indicating the importance he attached to his exposition of geometrical perspective.

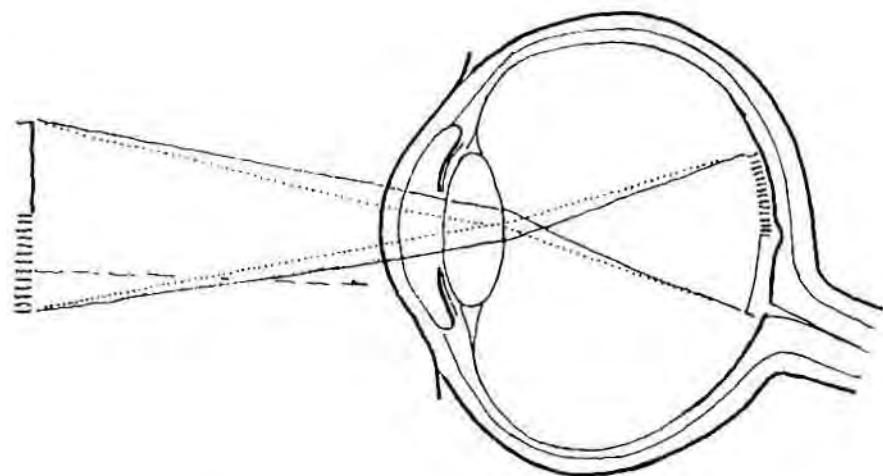
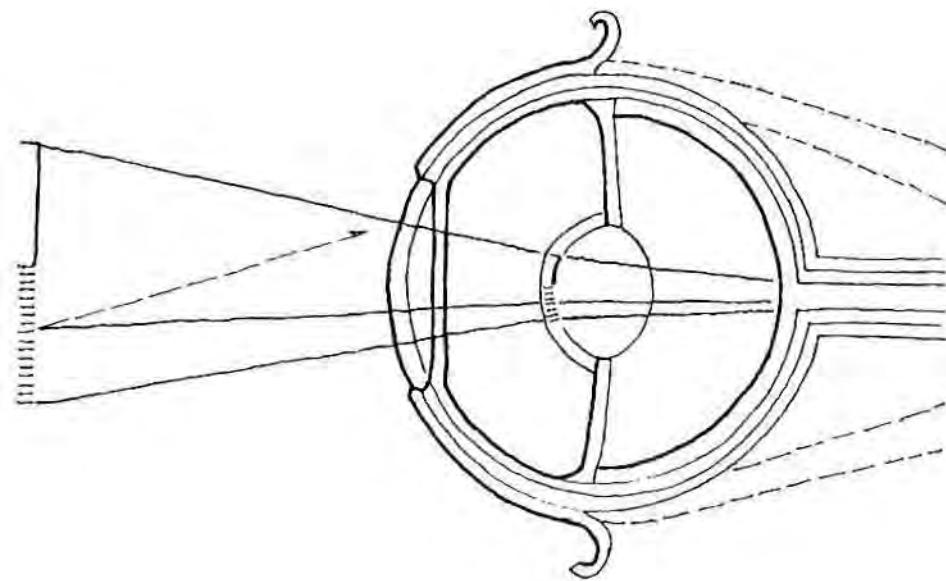


Fig. 5. Medieval concept of the mechanics of vision (top), Kepler's findings (bottom). The bottom drawing represents a horizontal section through the right eyeball.



Fig. 6. Sir Isaac Newton from an engraving in his Opticks. During the last twenty-five years of his life Newton turned his attention away from natural philosophy to biblical exegesis, and affairs of state.

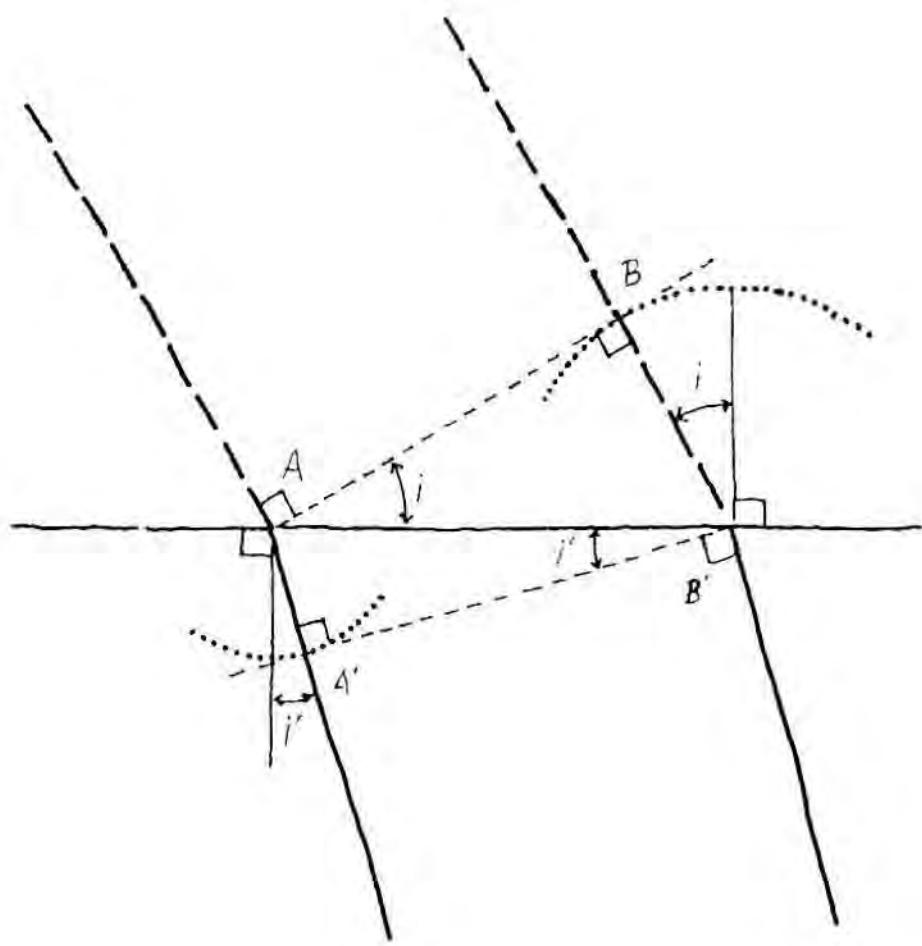


Fig. 7. Refraction explained by Huygen's principle.

OPTICKS:

O R, A

TREATISE

OF THE

*Reflections, Refractions,
Inflections and Colours*

O F

L I G H T.

The FOURTH EDITION, corrected.

By Sir *ISAAC NEWTON*, Knt.

L O N D O N:

Printed for *WILLIAM INNYS* at the West-
End of *St. Paul's*. M D C C X X X.

Fig. 8. Title page of the fourth edition of Newton's *Opticks*.



Fig. 9. Ludwig Hermann von Helmholtz in an early portrait.

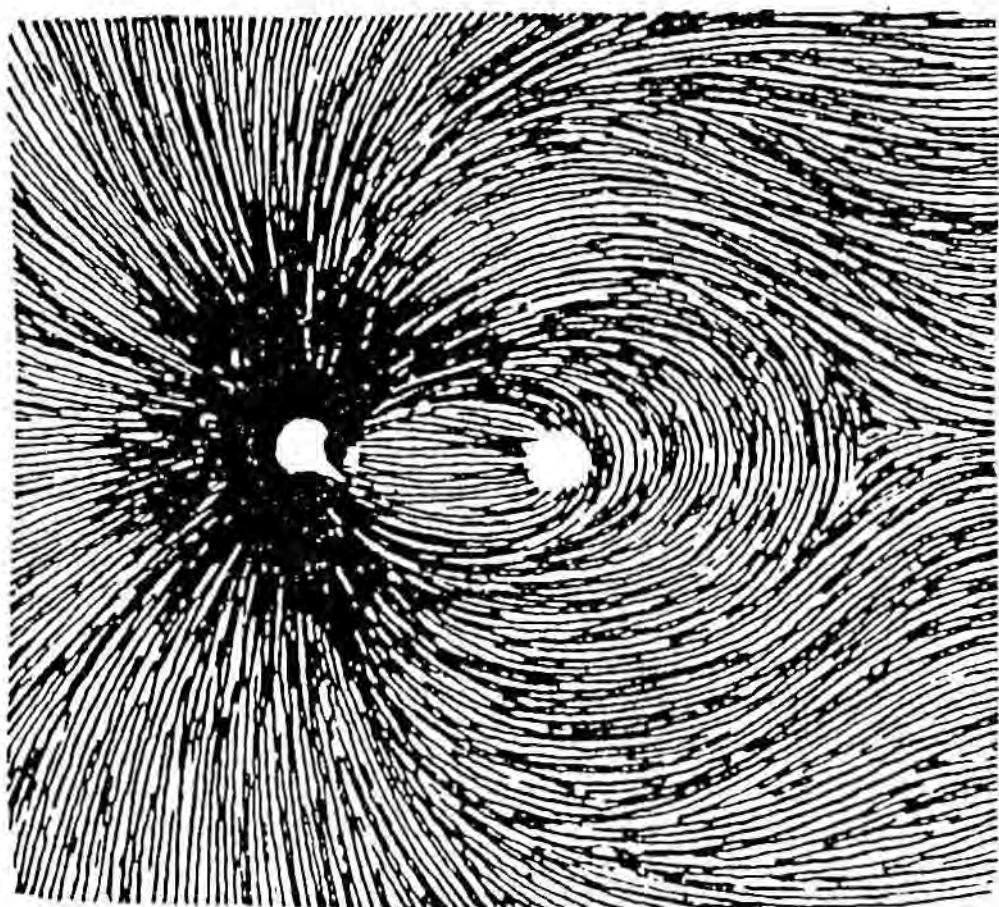


Fig.10. The retina where the optic nerve (left) exits the back of the eyeball, showing also the *fovea centralis* (right).

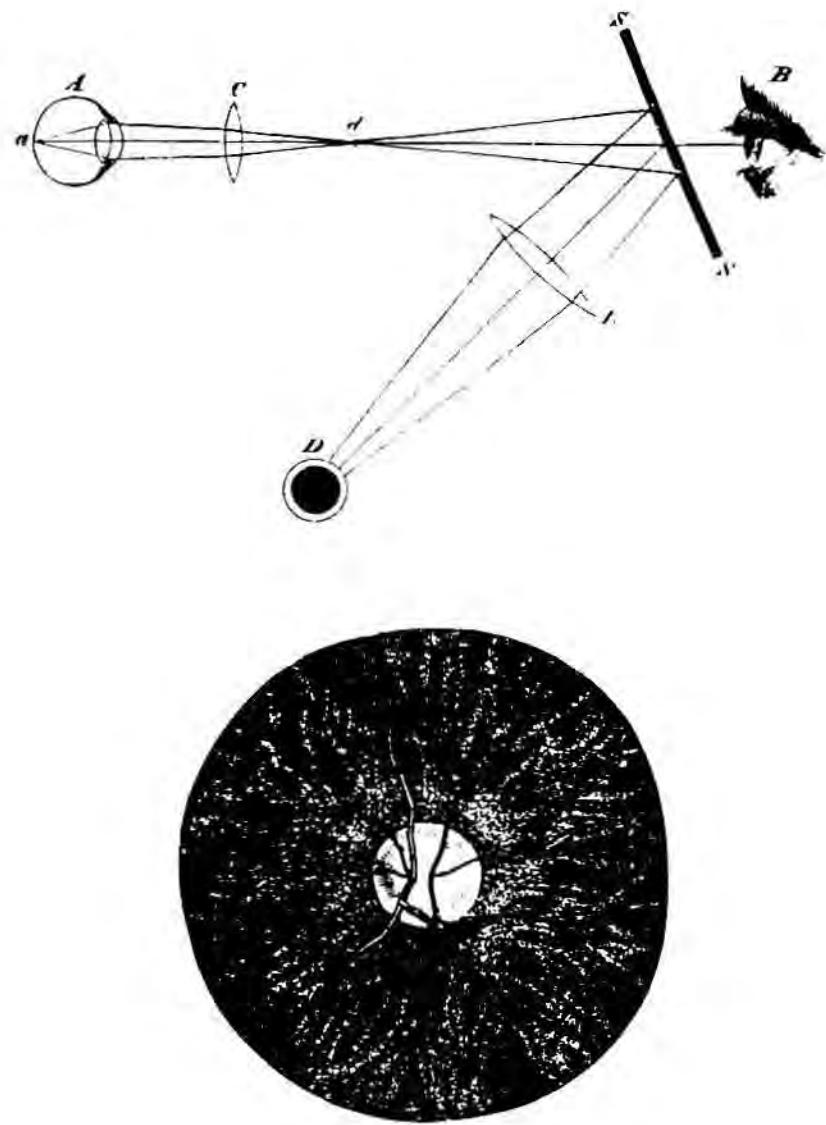


Fig. 11. Von Helmholtz invented the ophthalmoscope which he used to inspect the retina. Schematic of the instrument (top). View of the retina (bottom).

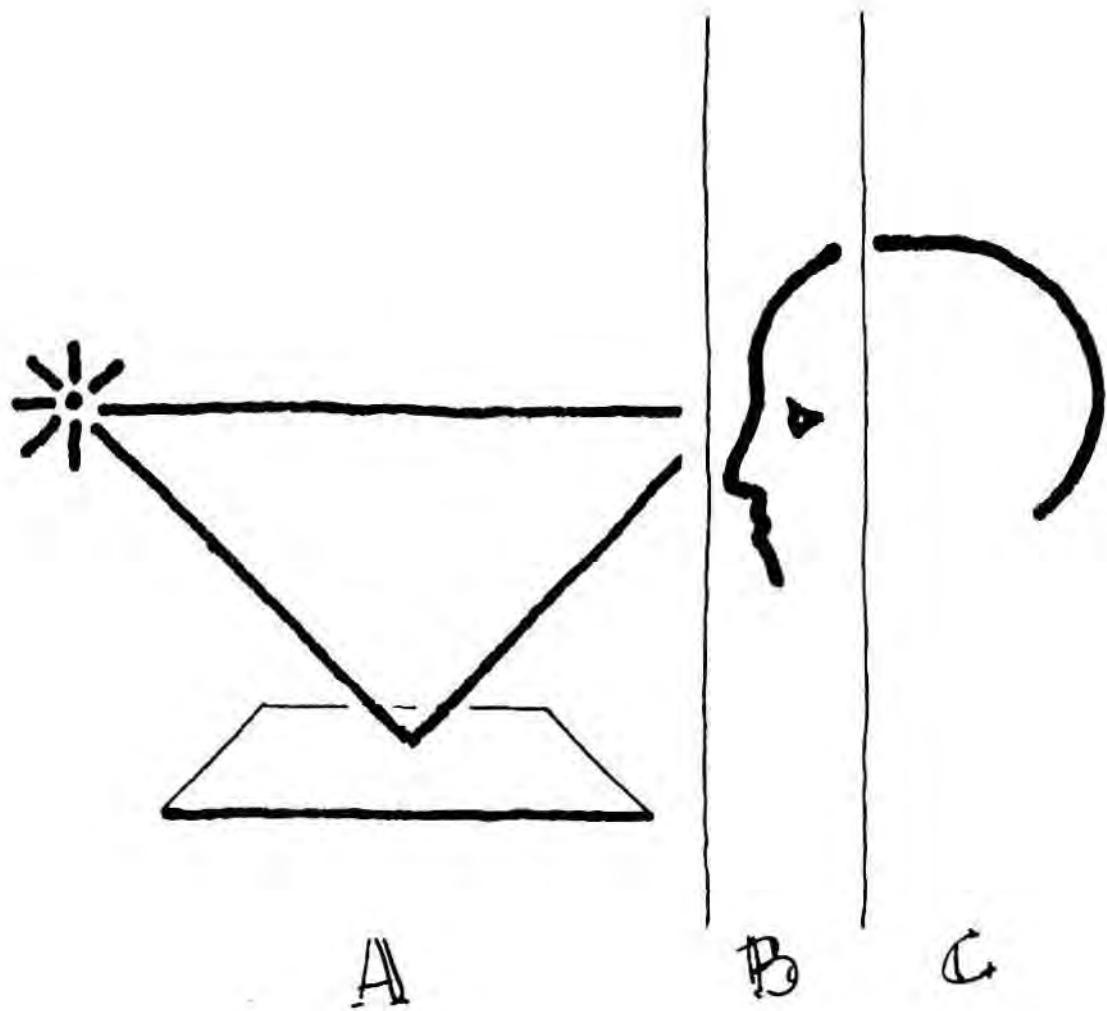


Fig.12. Diagrammatic description of the domain of physics (A), psychophysics (B) and psychology (C).

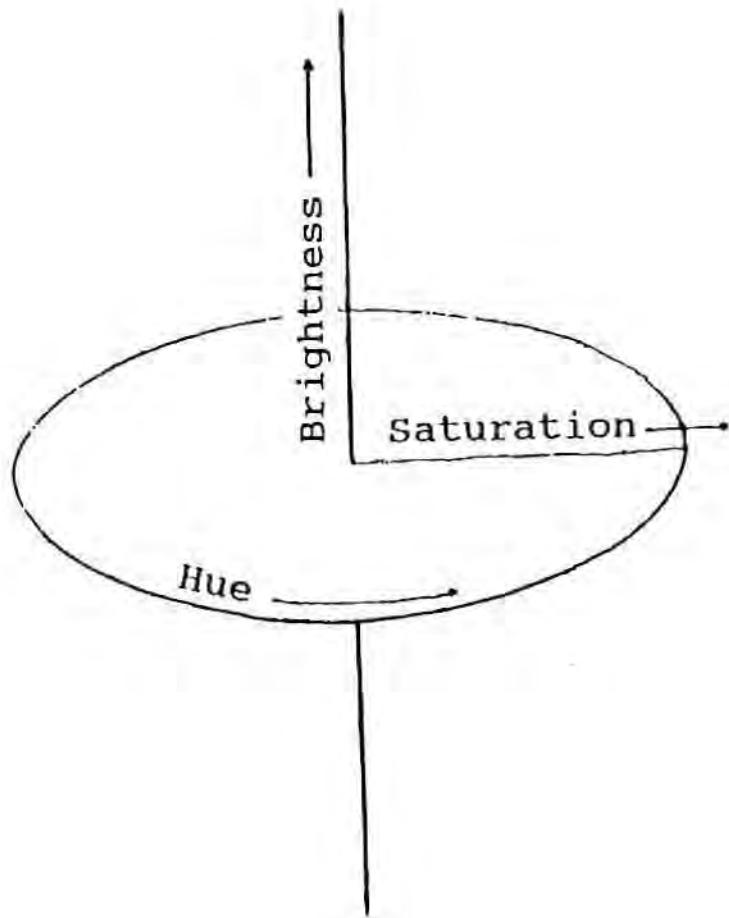


Fig.13. Schematic relationship of the attributes of sensation Brightness, Hue, Saturation in psychophysics which only approximately correspond to the terminology color, value, and intensity.

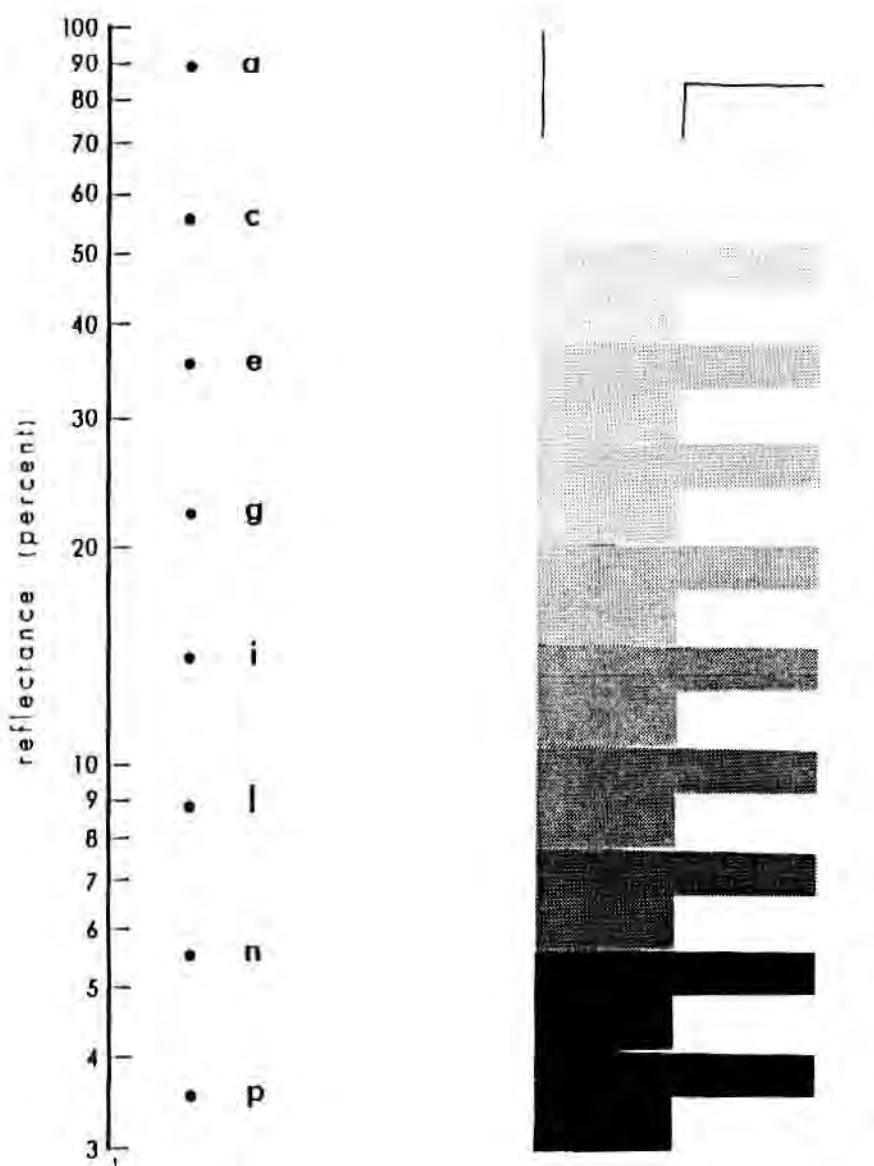


Fig.14. Value refers to pigment (right), brightness, refers to percent of reflectance (left). These concepts can be correlated, as they are here but, ultimately they refer to different perceptual phenomena.

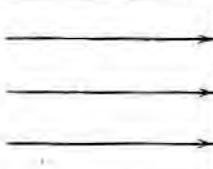
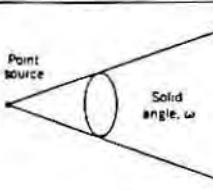
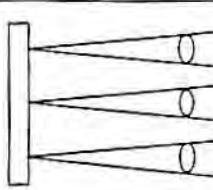
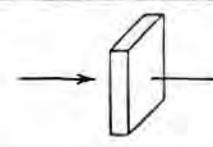
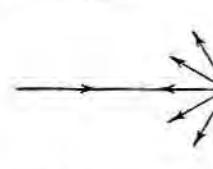
Geometry	Corresponding Radiant Term	Luminous Term	Symbol	Unit. mks
	Radiant energy	Luminous energy	Q	talbot
	Areal density of radiant energy	Areal density of luminous energy	Q/A	talbot/m ²
	Radiant flux	Luminous flux	F	lumen
	Irradiance	Illuminance (illumination)	E	lumen/m ² (lux)
	Radiant intensity	Luminous intensity	I	lumen/s (candle)
	Radiance	Luminance (photometric brightness)	B	lumen/s × m ² (candle/m ²)
	Radiant transmittance	Luminous transmittance		
	Radiant reflectance	Luminous reflectance		

Fig.15. Graphical definitions of the geometry of radiant energy.

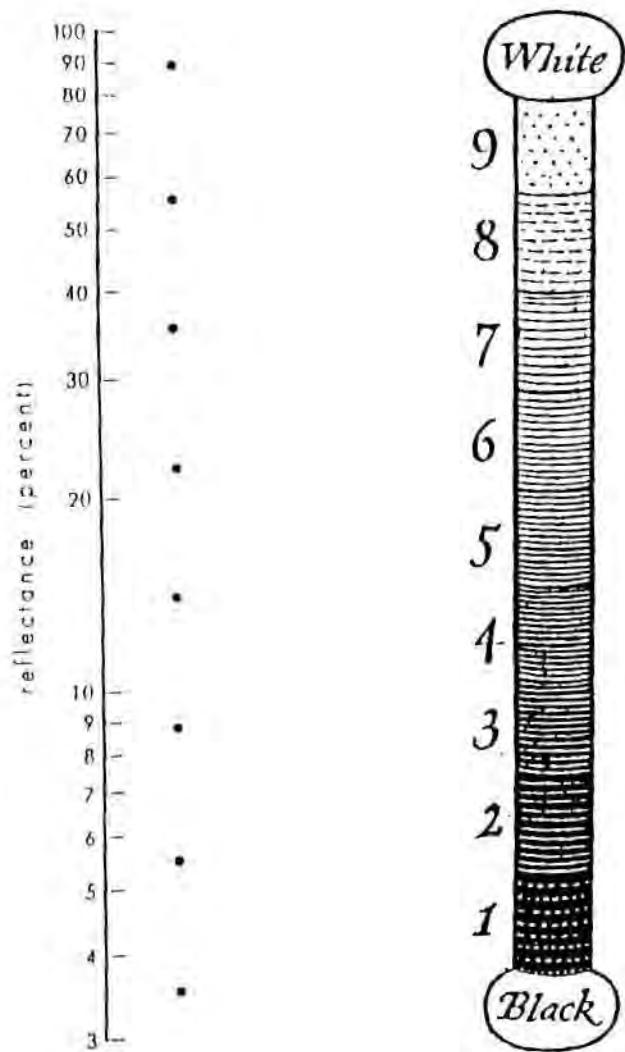


Fig. 16. Munsell's scale of value.

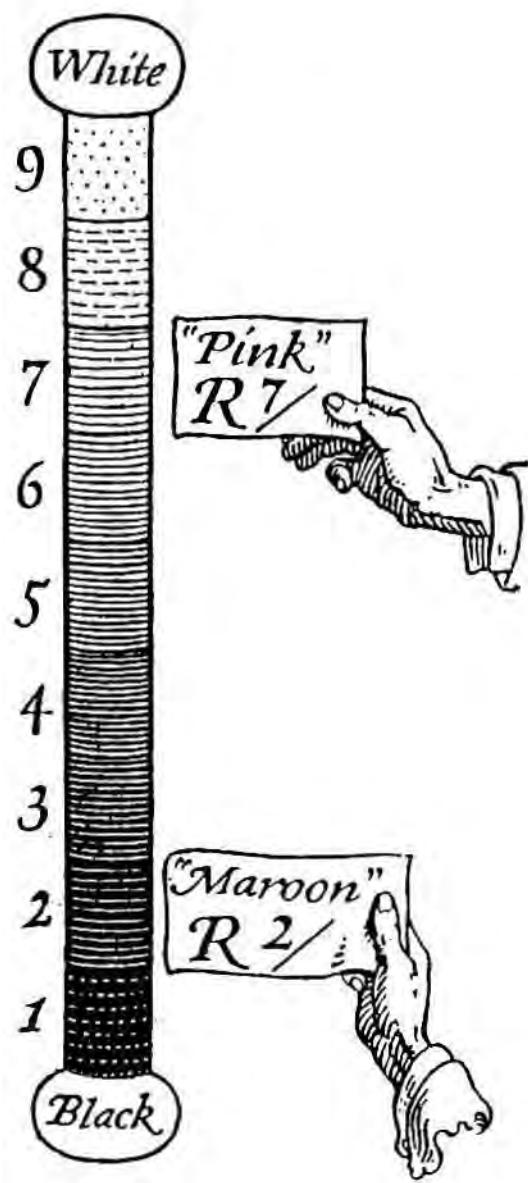


Fig.17. Saturated yellow occurs at value level eight. Saturated blue occurs at value two.

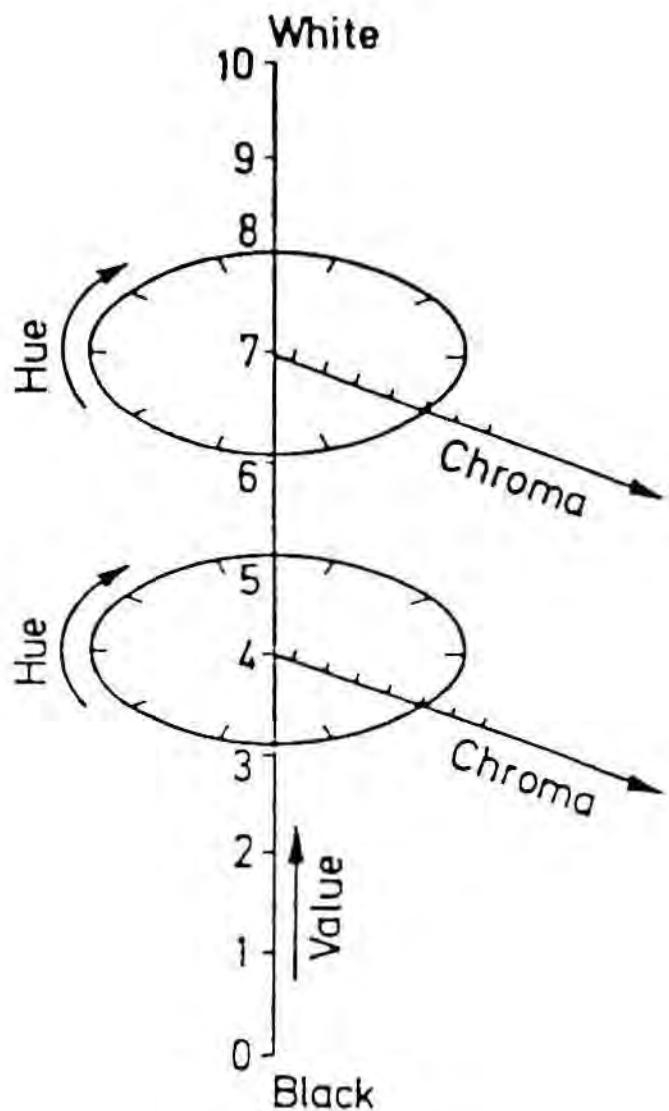


Fig.18. Munsell's color space, like Alberti's color space, is not a fully articulated three dimensional space. Colors may relate on a foliation of constant hue varying in chroma and value or they may relate on a layer of constant value varying in hue and chroma.

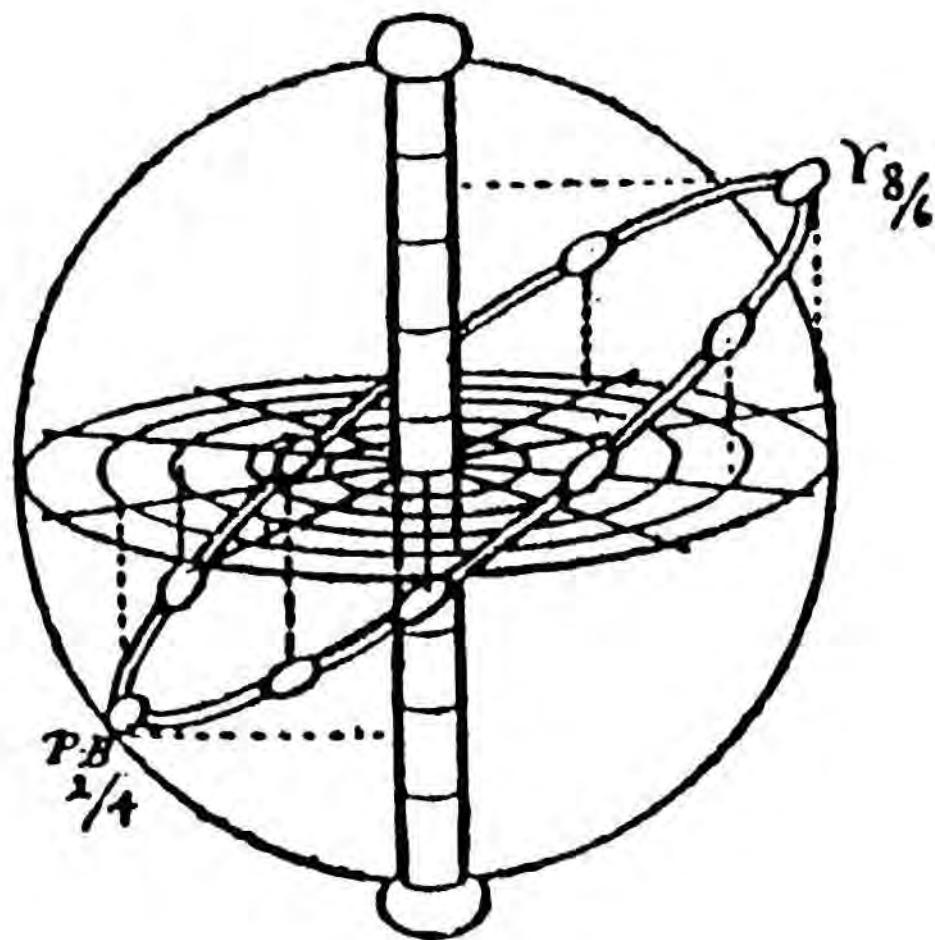


Fig.19. Cleland's drawing that insinuates a relationship of constant chroma in Munsell. Hue of maximum chroma are located on a specific plane of constant value. Since unitary blue is dark, sky blue can not be of equivalent chroma at its level of value. Sky blue, maximally saturated has no local habitation in Munsell.

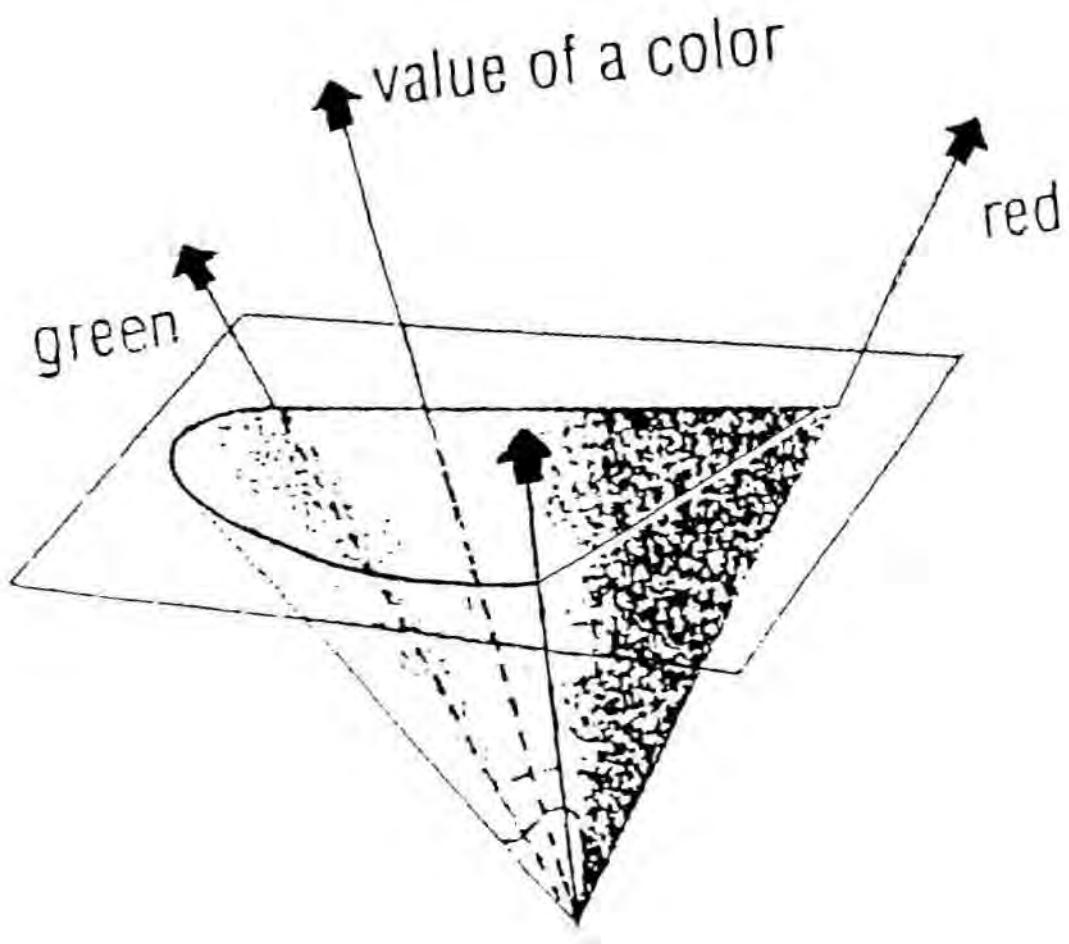


Fig. 20. MacAdam's 1935 three dimensional formulation of the chromaticity diagram.

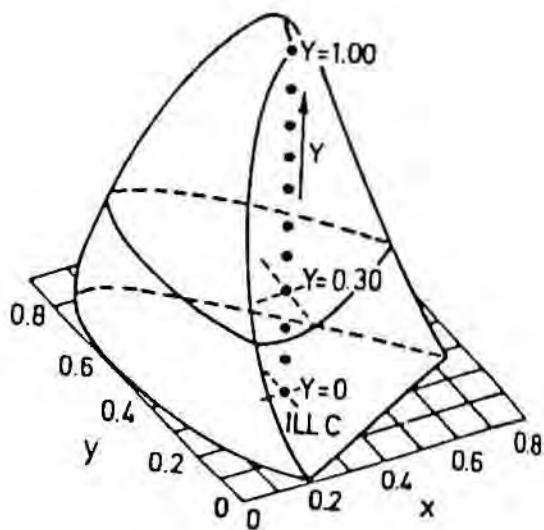
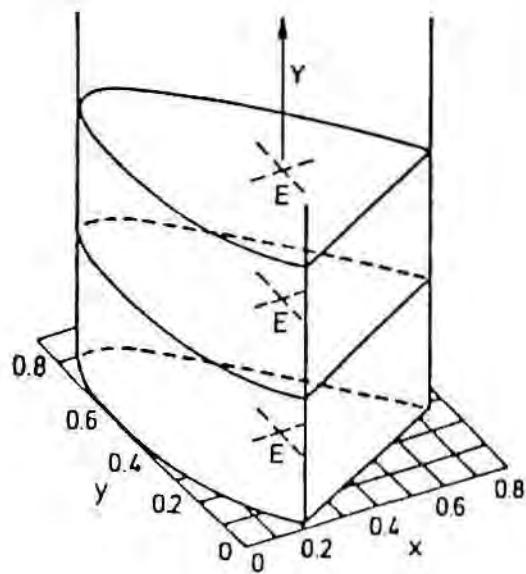


Fig.21. Graphical definitions of the differences between the space of the self luminous colors (top) and the space of object colors (bottom).

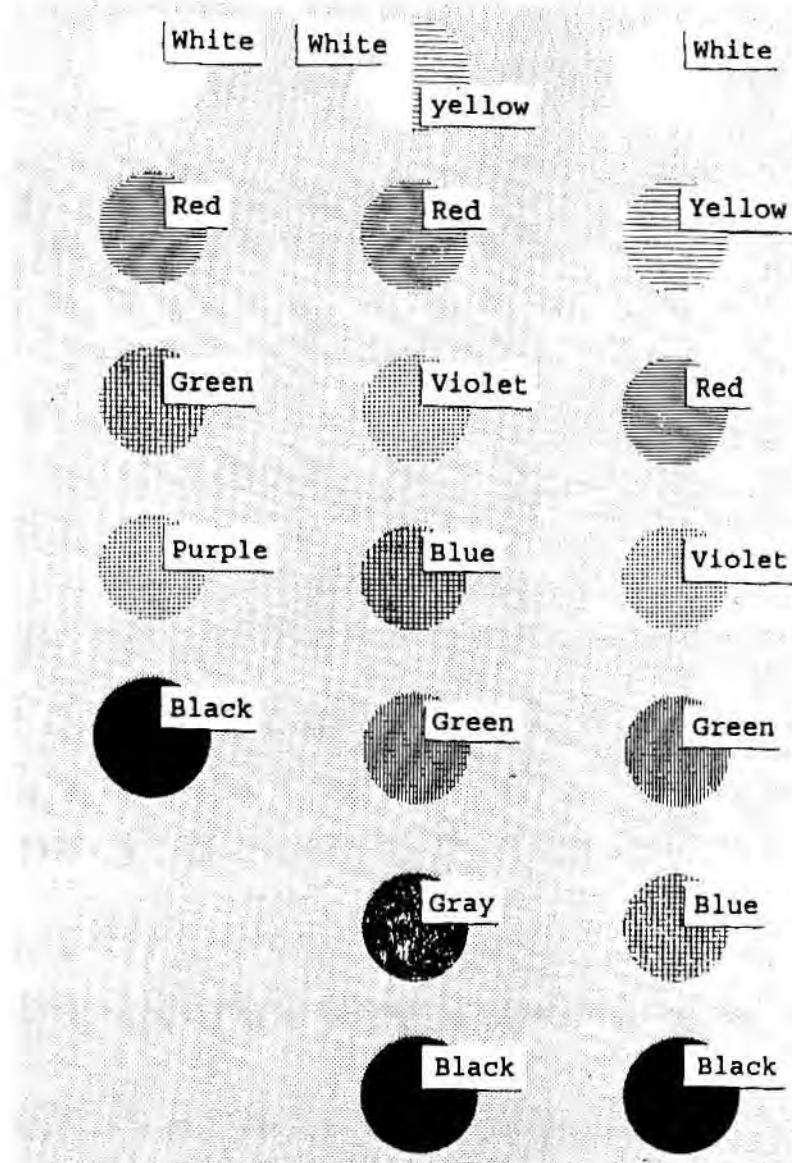


Fig. 22. Aristotle's color schema. The primary colors are white and black. All other colors are a product of their combination. (A) from *Meteorologica*. (B) and (C) from *On Sense*

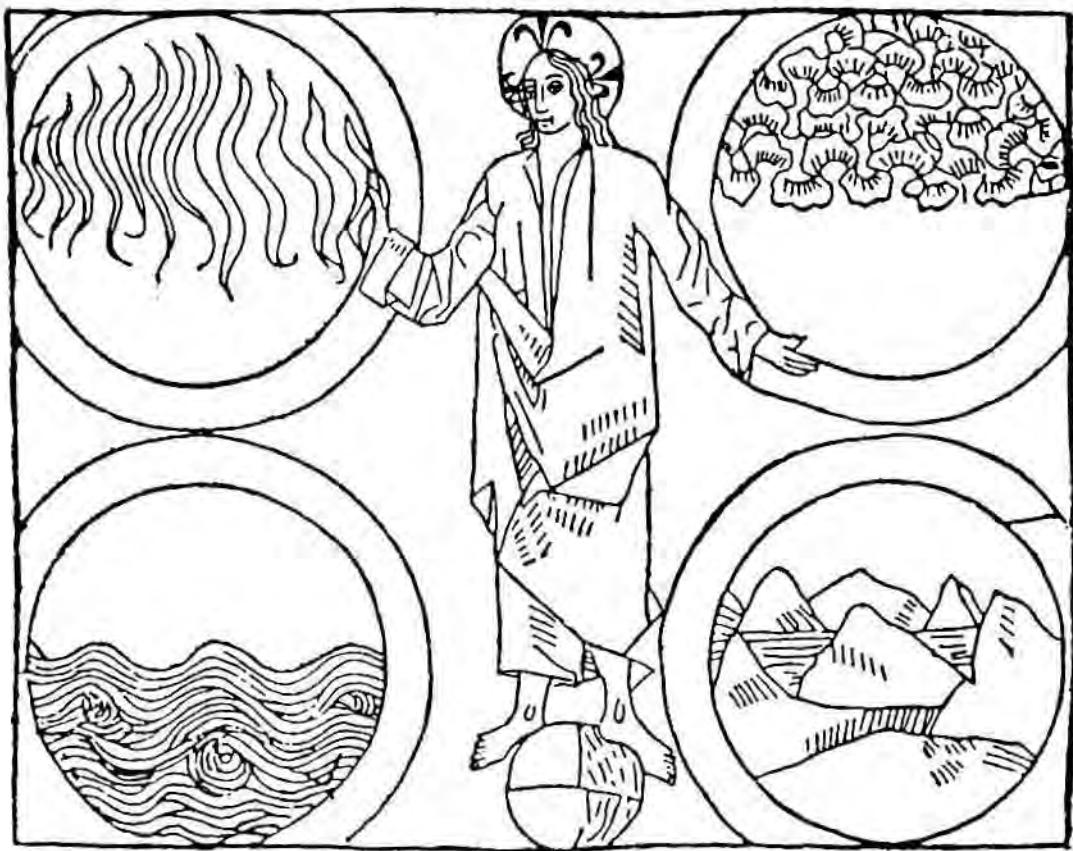


Fig.23. Medieval graphic depiction of the four elements. God is at the center, standing atop the world. Note the rendering of clouds for air.

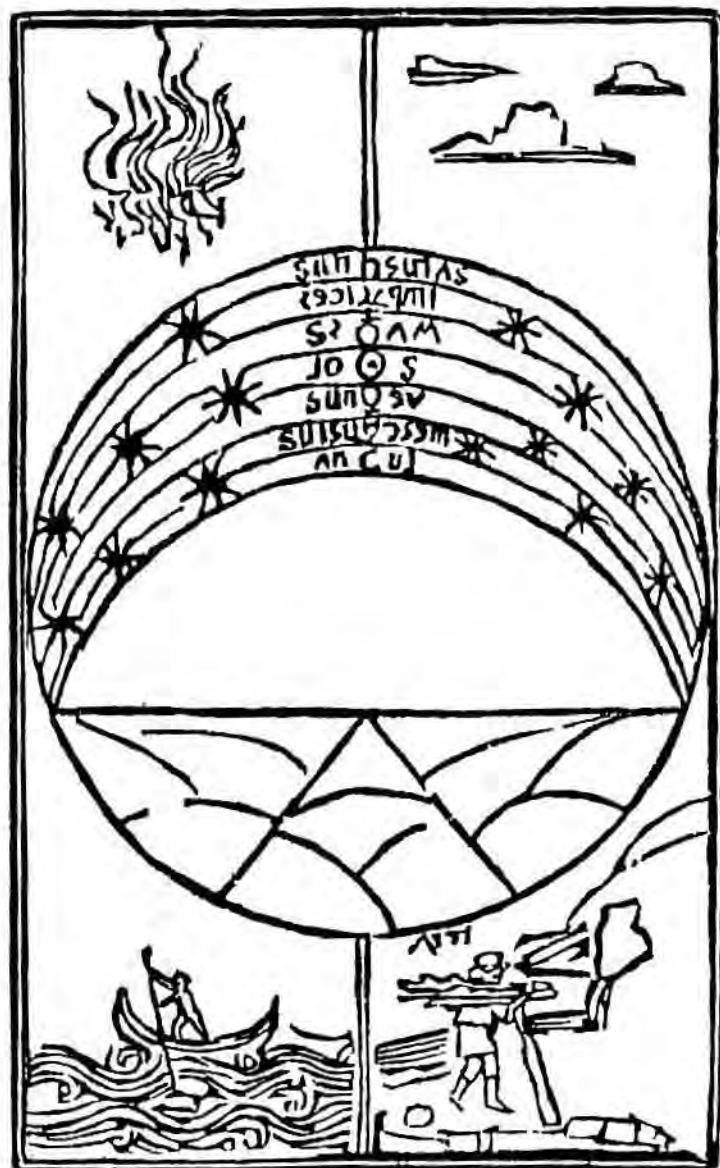


Fig.24. Renaissance graphic depiction of the four elements.
The cosmos is at the center of this depiction. Note clouds
for air.

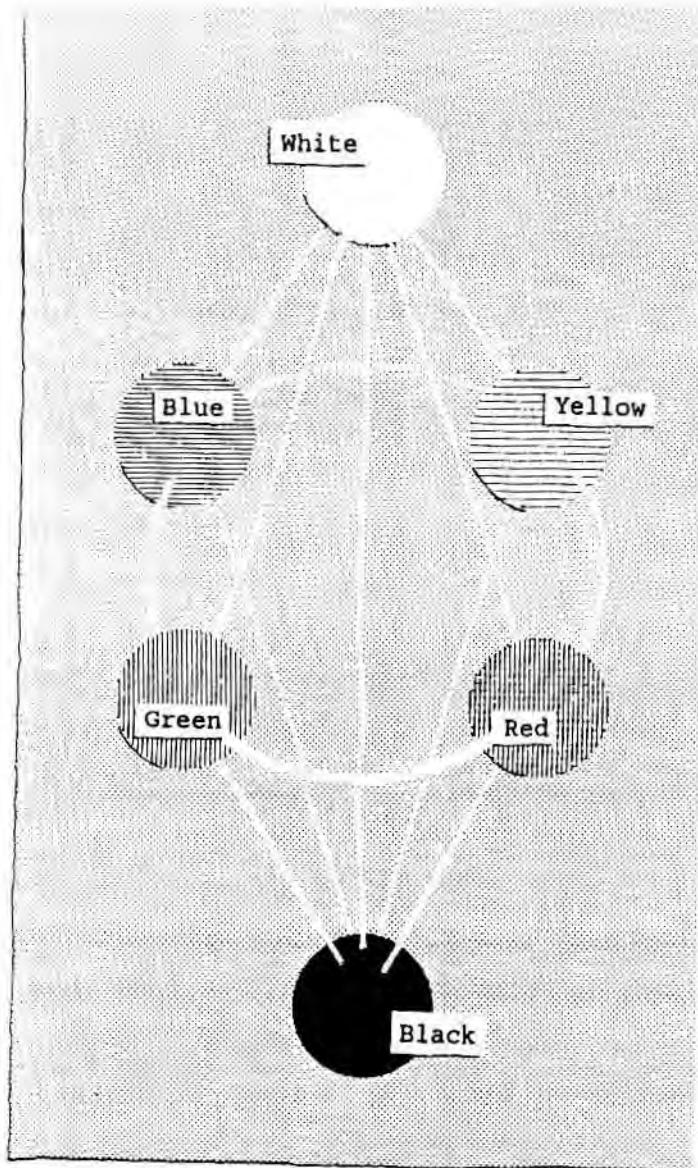


Fig.25. Alberti's color space composed of four triangular plane spaces (in vertical section) plus one horizontal plane space (in plan ssection).

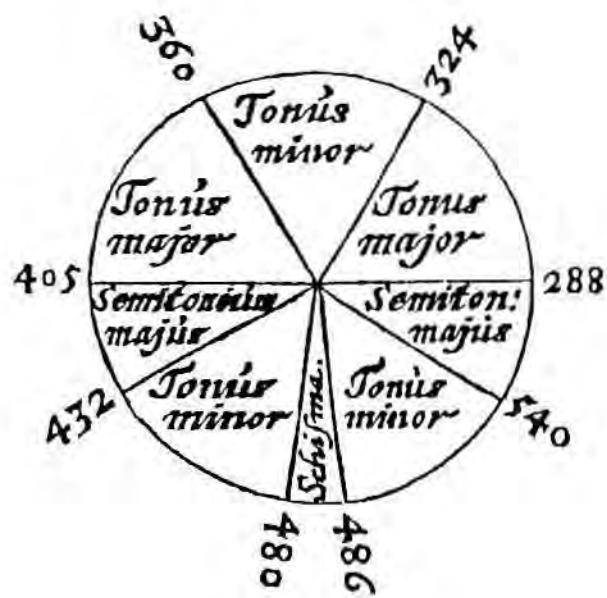
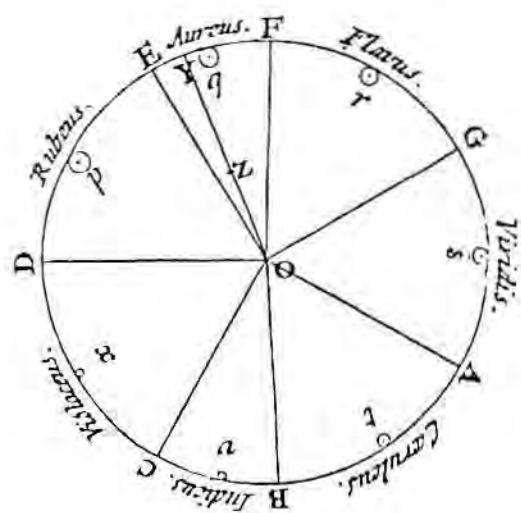


Fig. 26. Newton's color harmonics (top) derived from Descartes tonal circle (below) of major and minor tones (*Compendium Musicae*, 1650).

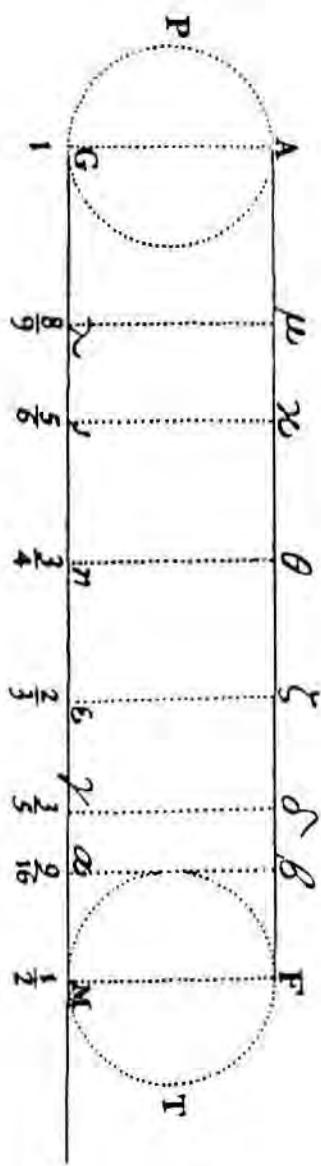


Fig. 27. Newton realized Descartes' promise of a mechanistic theory of color by minutely observing color phenomena in his experiments, but Newton's greatest conceptual breakthrough (even he did not realize the significance of) was unwrapping the color circle into a line he called the "spectrum."

Spectrum

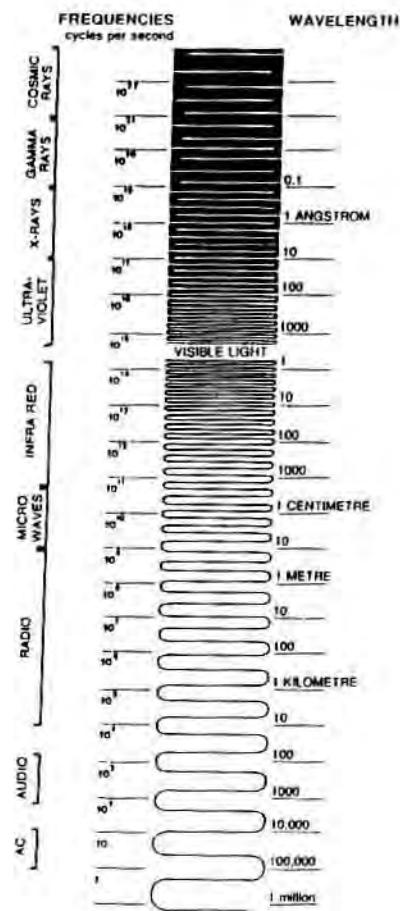


Fig. 28. Newton's deceptively simple concept became the electromagnetic spectrum. Newton named it the "spectrum" because it was not "corporeal."

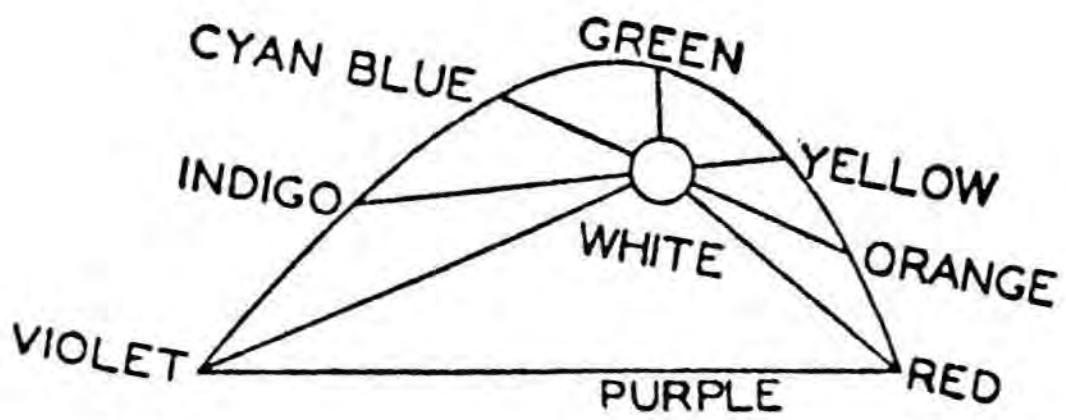


Fig. 29. Von Helmholtz color diagram from 1860.

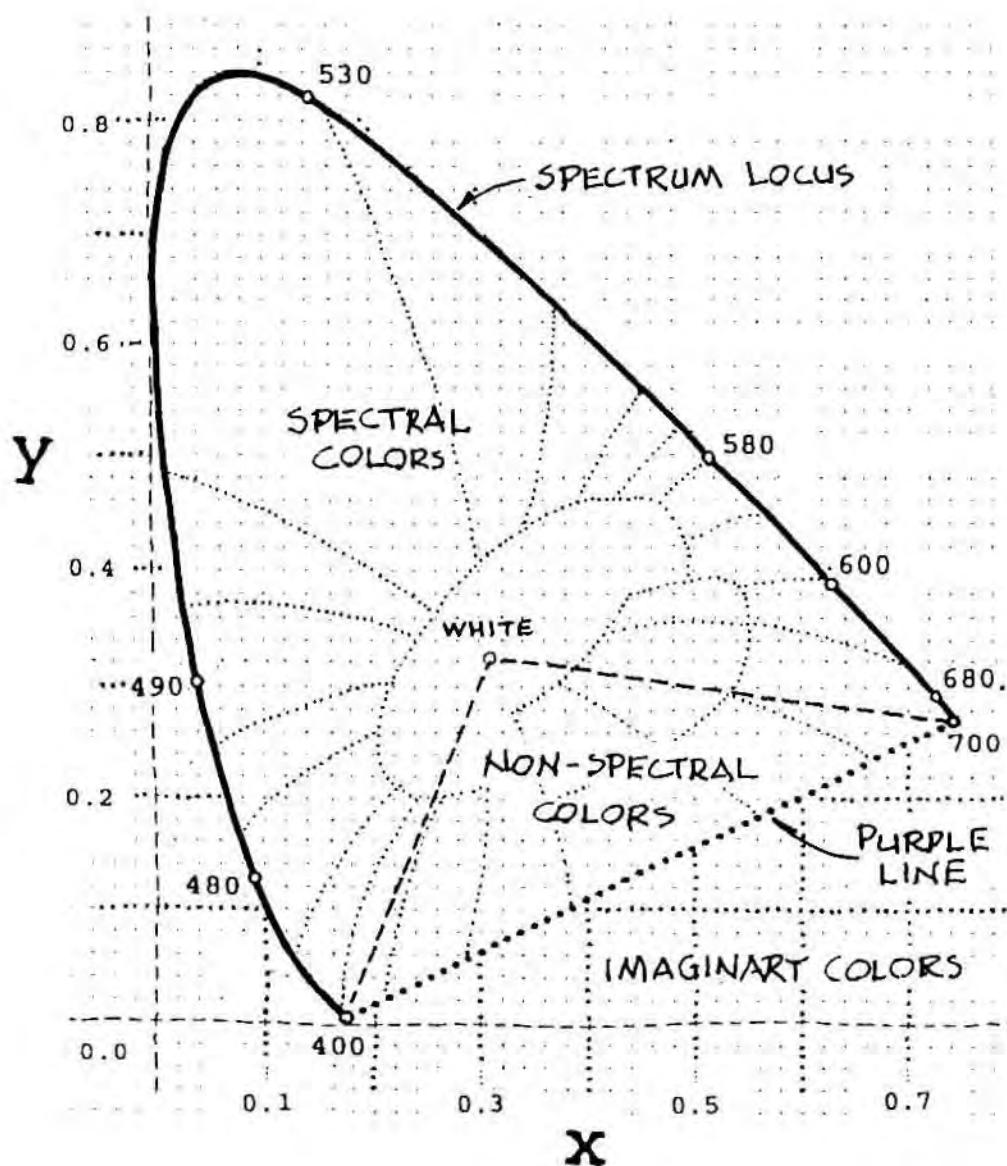


Fig.30. CIE (1931) chromaticity diagram showing locations of non-spectral colors, imaginary colors, purple line, spectrum locus and the white point.

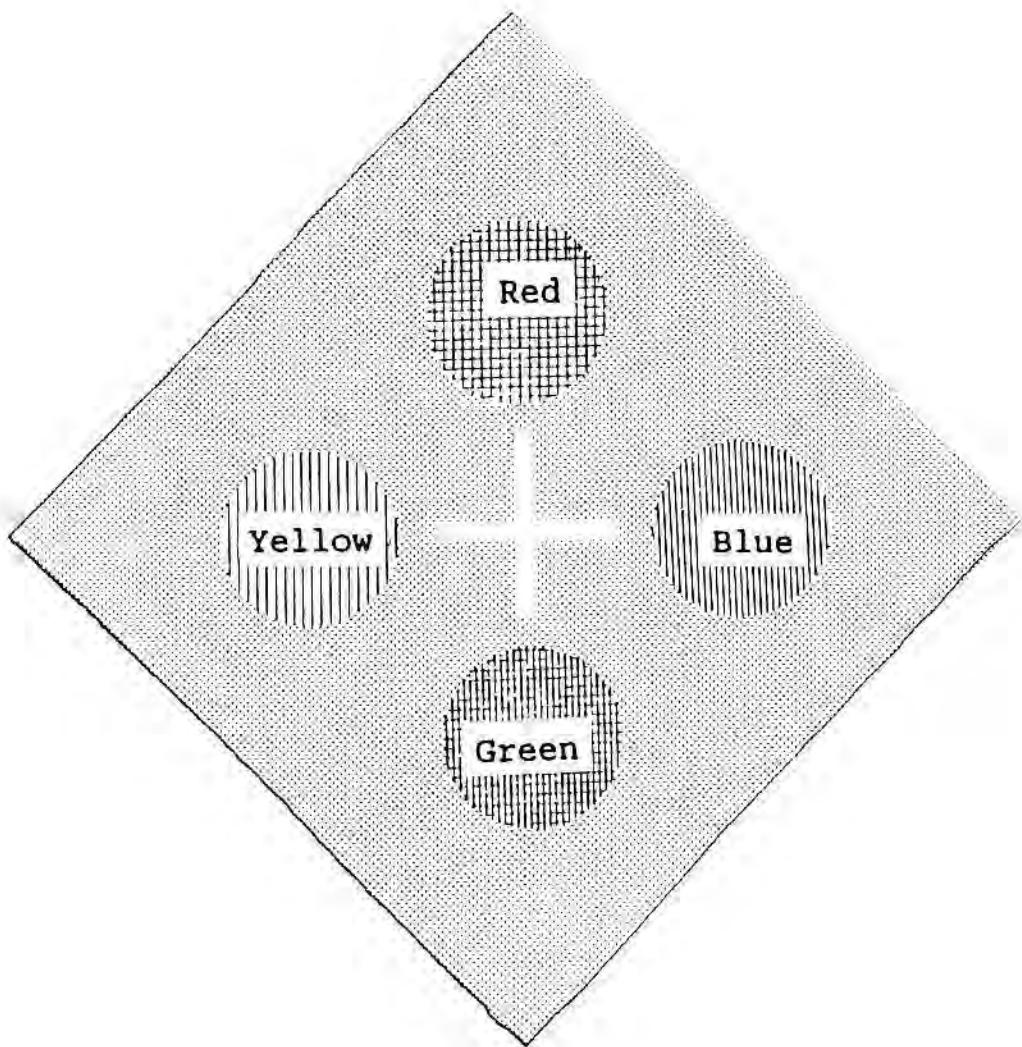


Fig.31. Basic opponent mechanism.

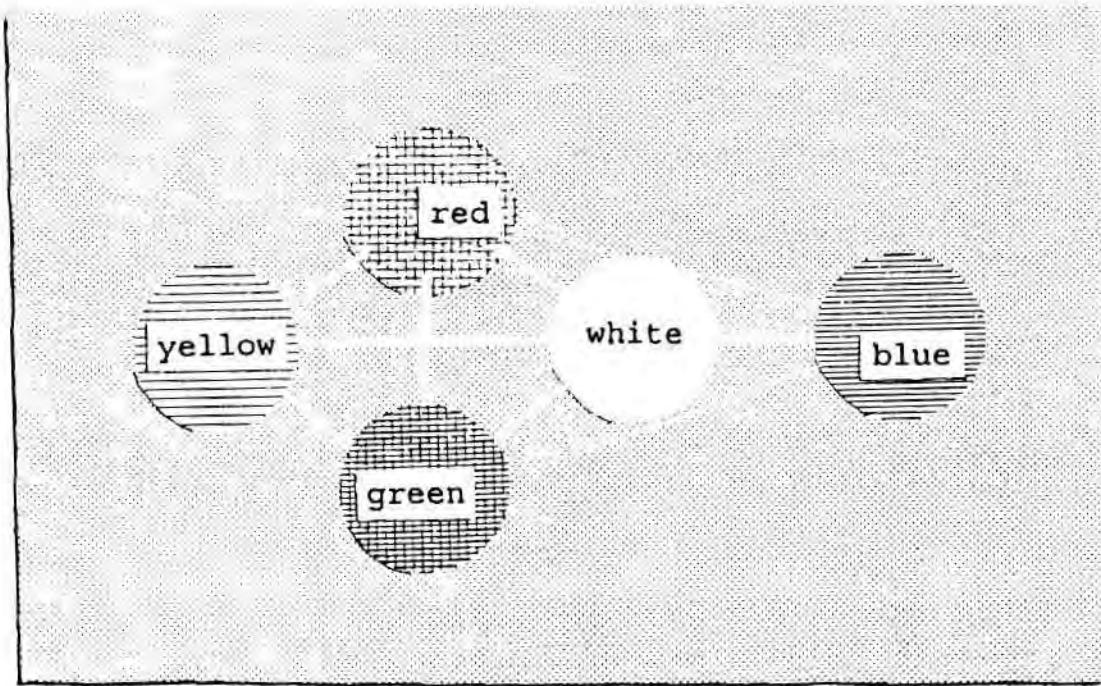


Fig.32. Revised opponent color mechanism. Color signals on red, green and blue channels combine to create white. Red and green signals combine to create yellow. Blue is given on a separate channel.

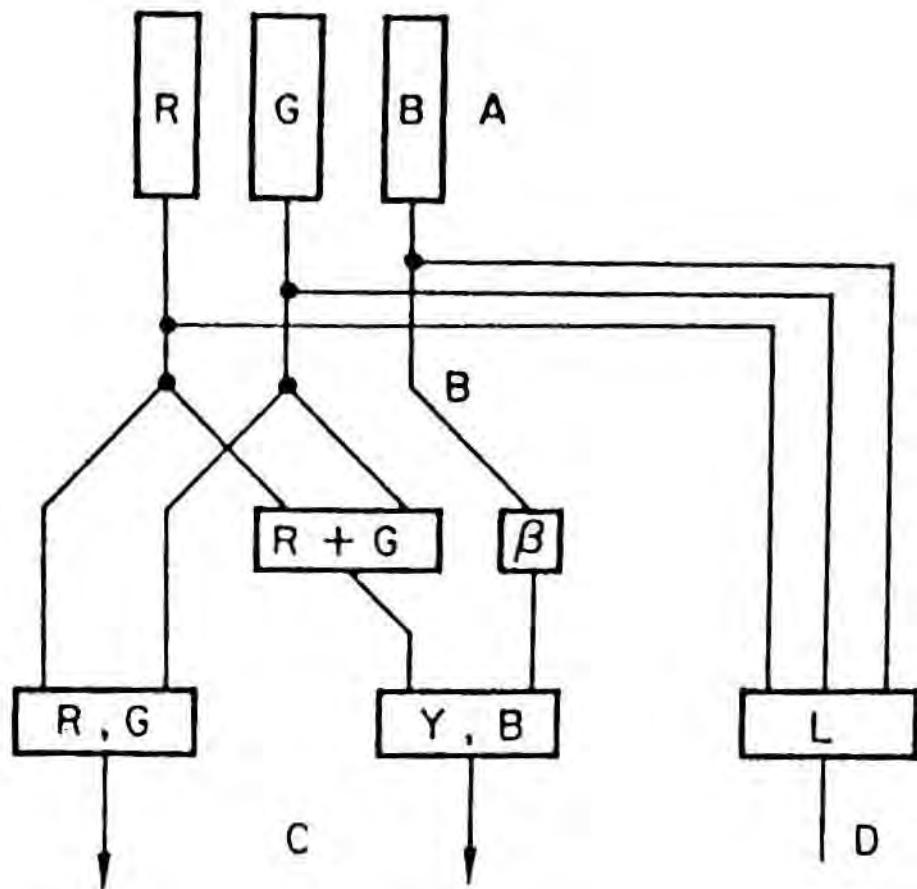


Fig.33. Walraven's model of the opponent mechanism. Sensory receptors are represented at (A). Information from different channels to create the red/green and the yellow/blue response at (C) and the response to luminance (psychophysical correlate of brightness) at (D). The precise nature of the hard wiring at (B) is still debated.

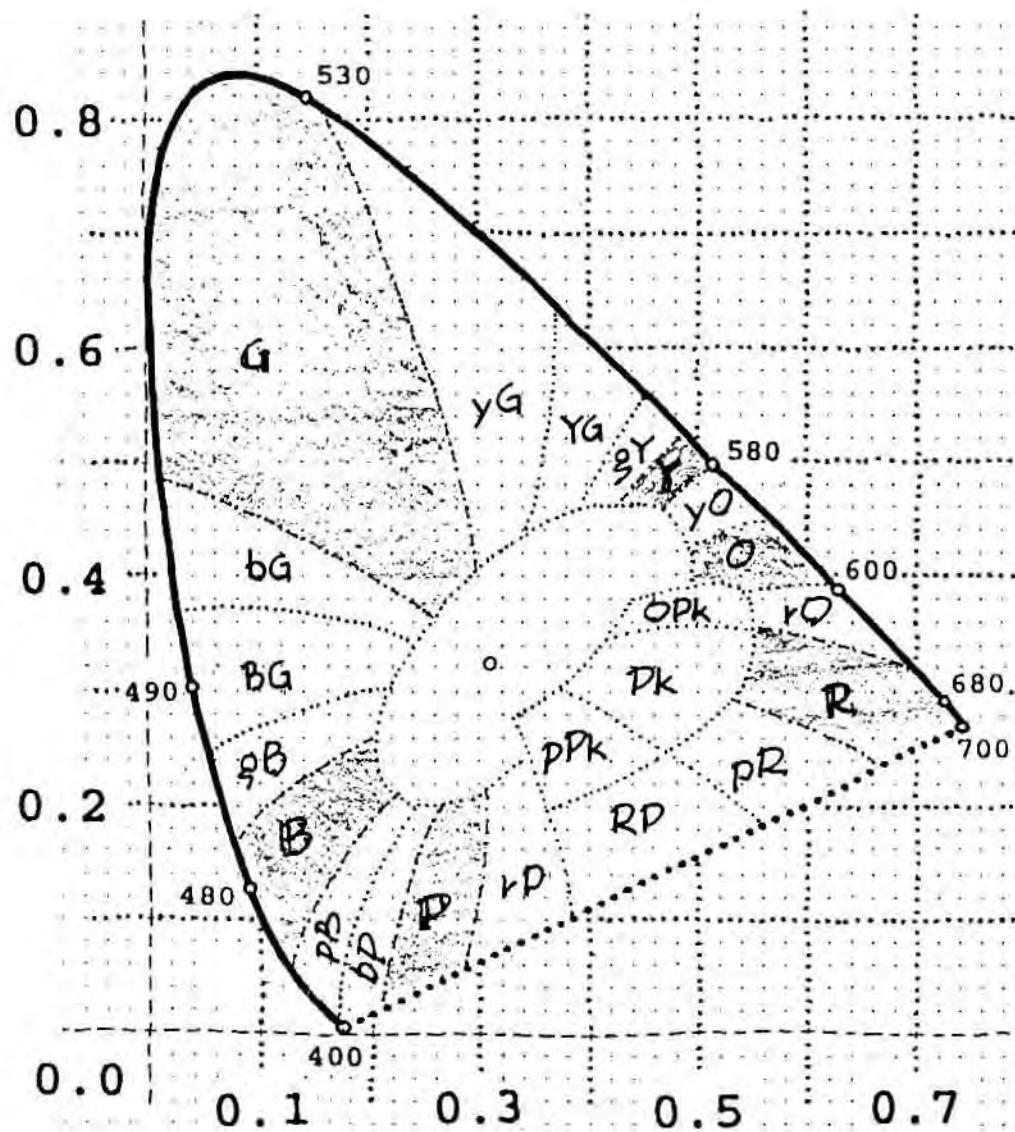


Fig.34. Characteristic color names and their location in the space of the CIE (1931) chromaticity diagram.
 G=green, Y=yellow, R=red, P=purple, B=blue.

ISCC-NBS

Purple

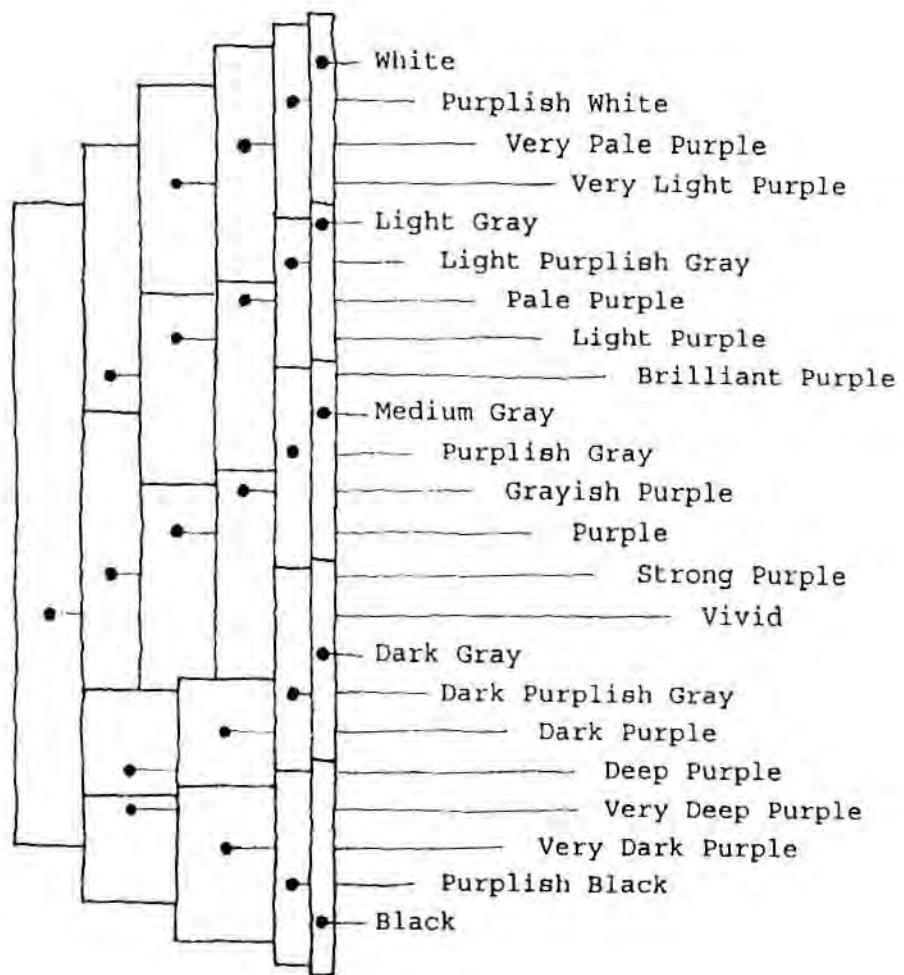


Fig. 35. The systematic modification of the species name "purple" in the ISCC-NBS color vocabulary.

ISCC-NBS

~ = Color Name

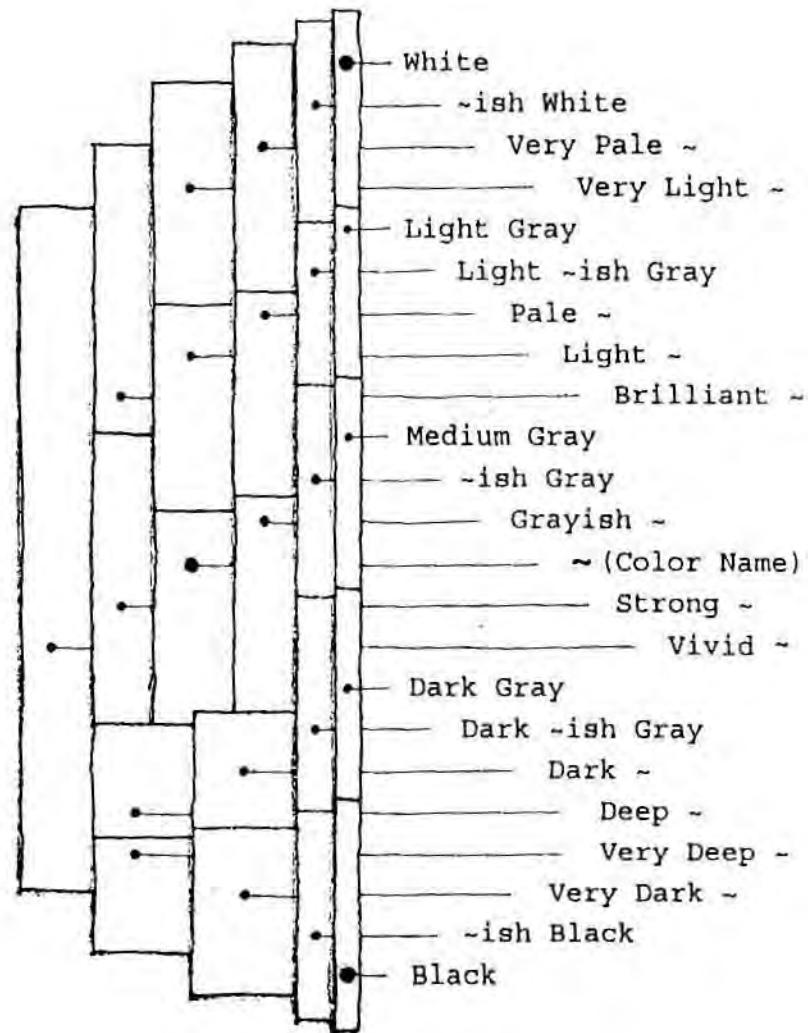


Fig. 36. Schematic layout of modifiers from the ISCC-NBS color vocabulary. Different species of color may have fewer modifiers (brown and olive) or more modifiers (red). Note the location of the characteristic name in the array.

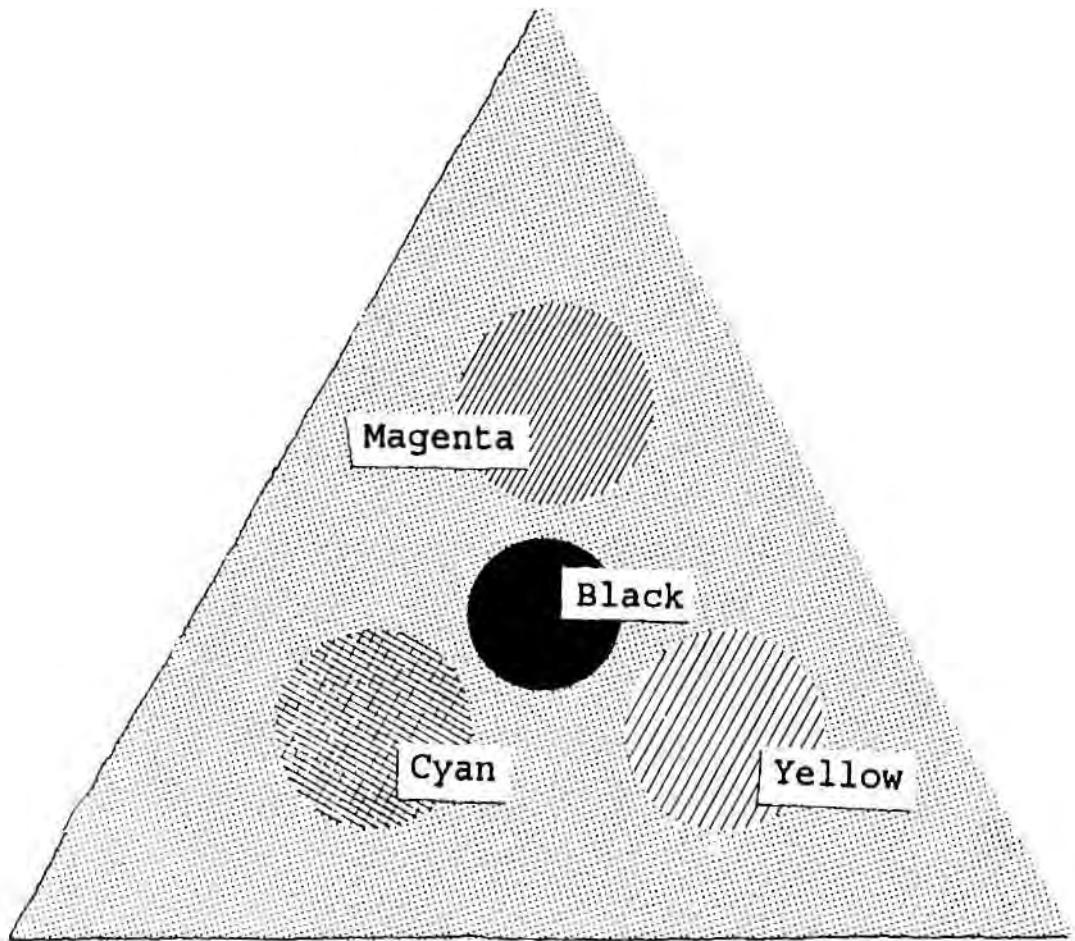


Fig.37. Subtractive color mixing primaries. This diagram is also exemplary of "process" colors used as primary colors by printers. magenta (red) + cyan (blue) + yellow = black.

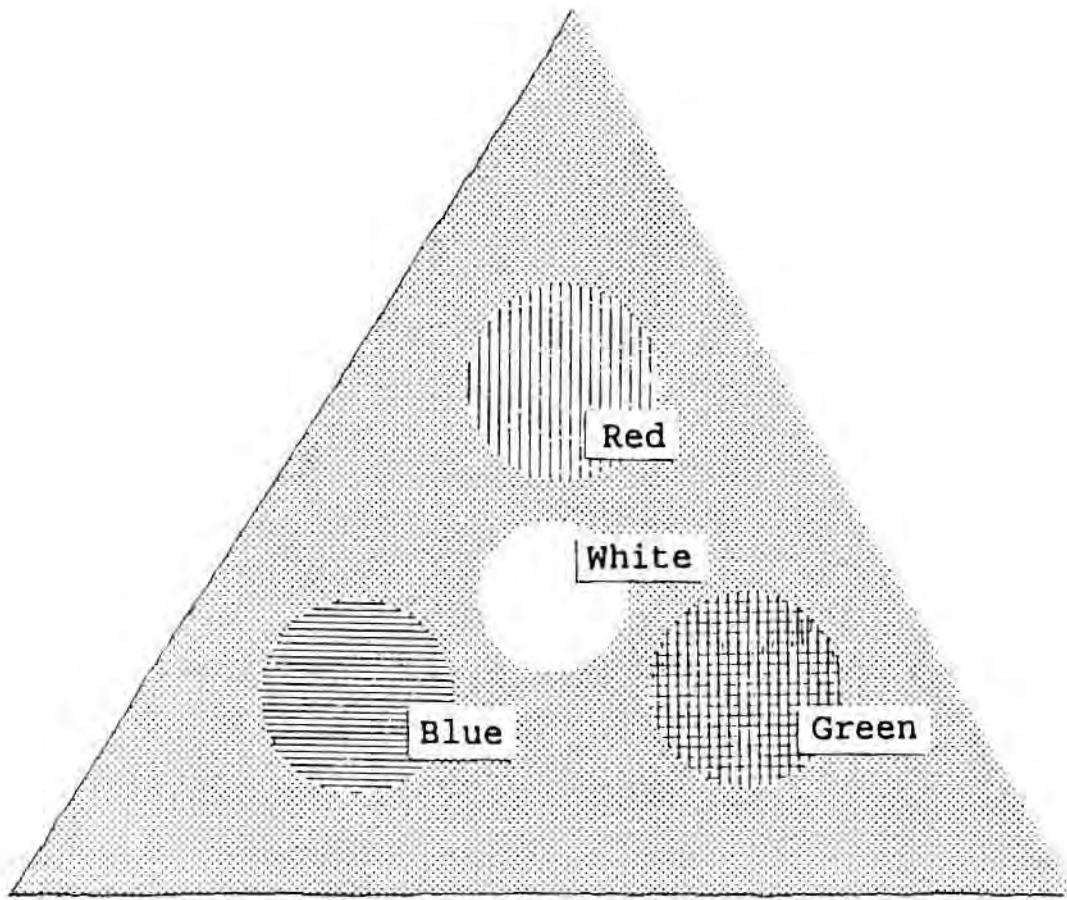


Fig.38. Colored lights of colorimetric experiments; exemplary of additive color mixing.
red = 700nm green = 546nm blue = 436nm

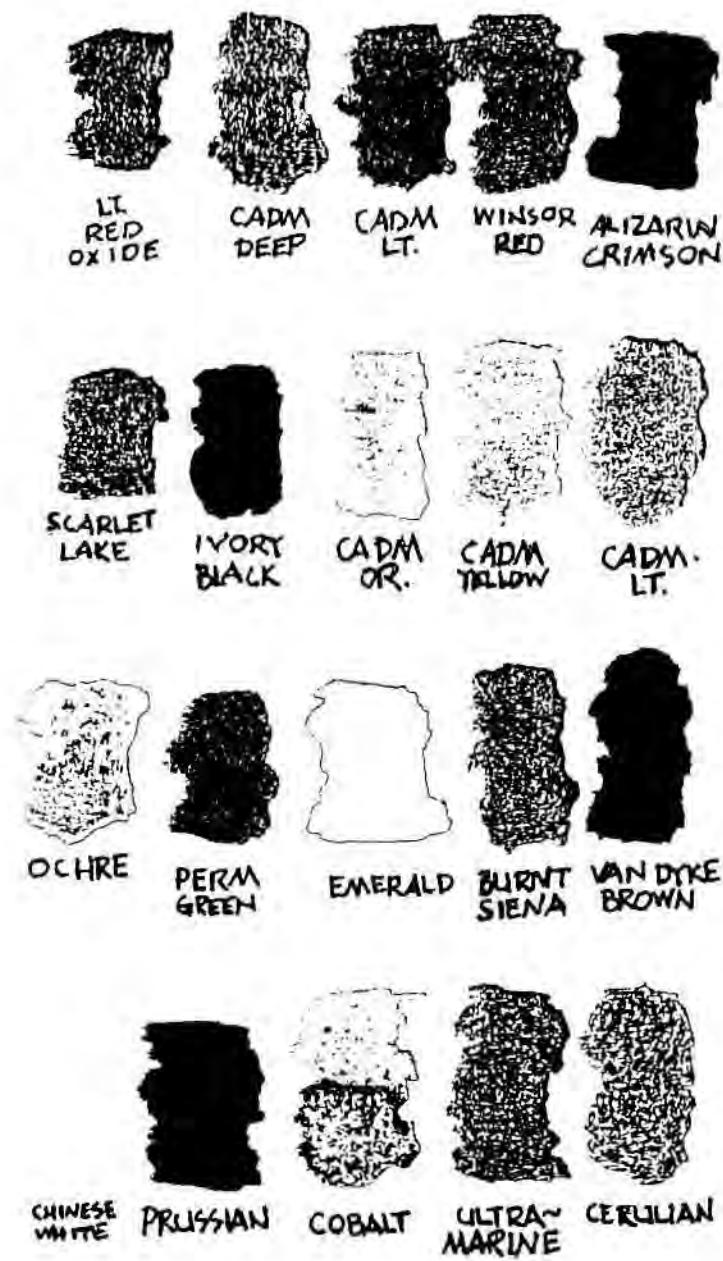


Fig. 39. The color vocabulary of painter's pigments is an excellent source for the beginnings of a rich vocabulary of color names, but you have to use the pigments as the point of reference and not printed color charts.

Psychology

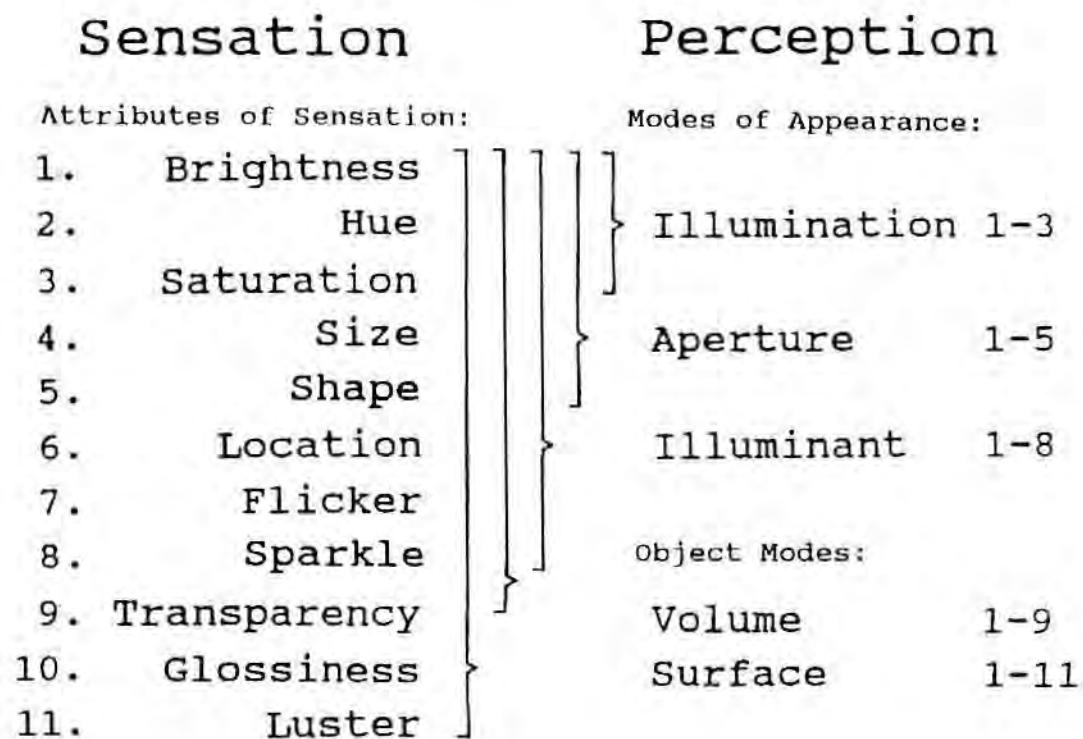


Fig.40. Relationship between the attributes of sensation and the modes of appearance.

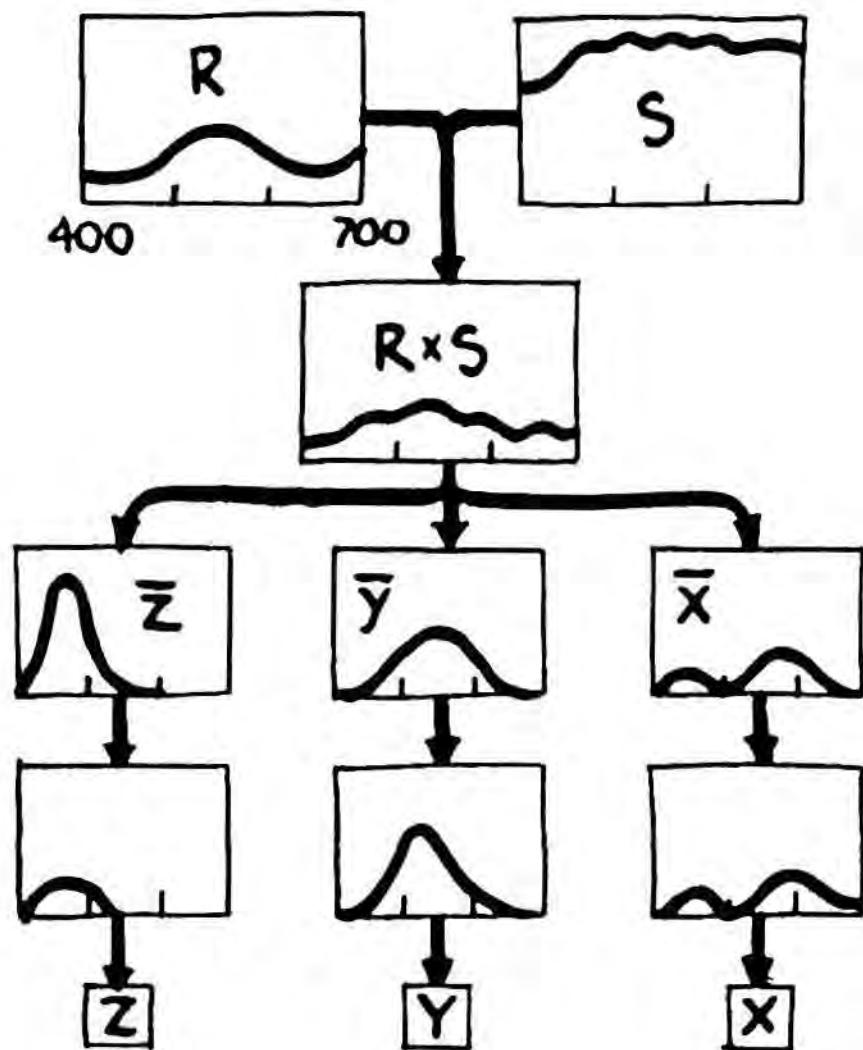


Fig.41. (R) is the reflectance of the surface. (S) is the spectral distribution of illumination. (B) sums (R) and (S). (C) filters (B) through the response curves of the mathematical correlates (\bar{z} , \bar{y} , \bar{x}) of the retinal sensors of a standard observer. (D) is the spectral distribution of the reflected light given in terms of (Z, Y, X) called tristimulus values.

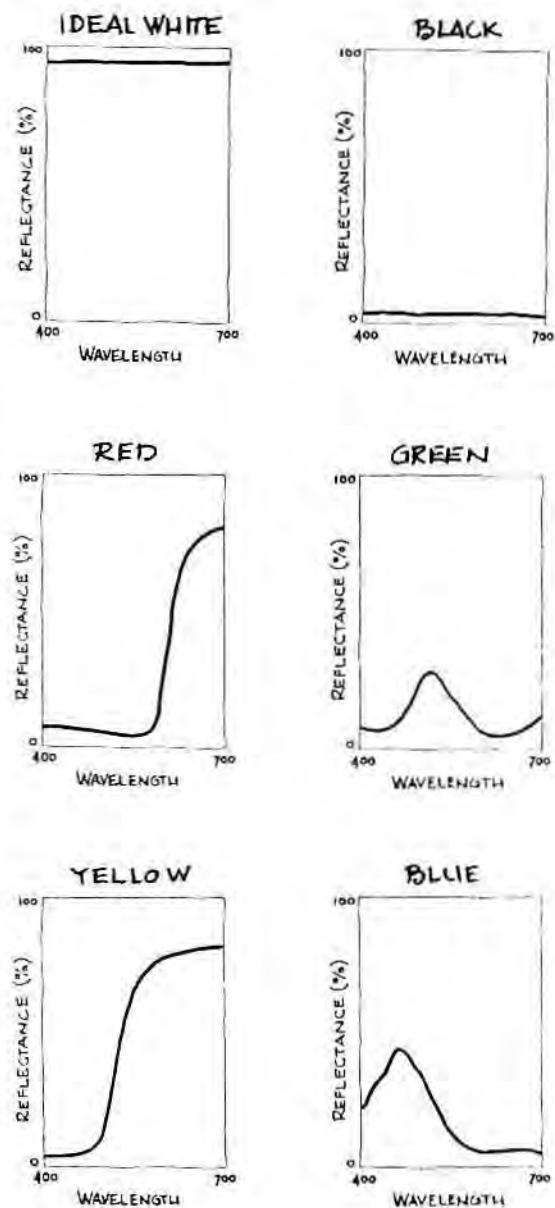


Fig. 42. Spectral signature of ideal colors.

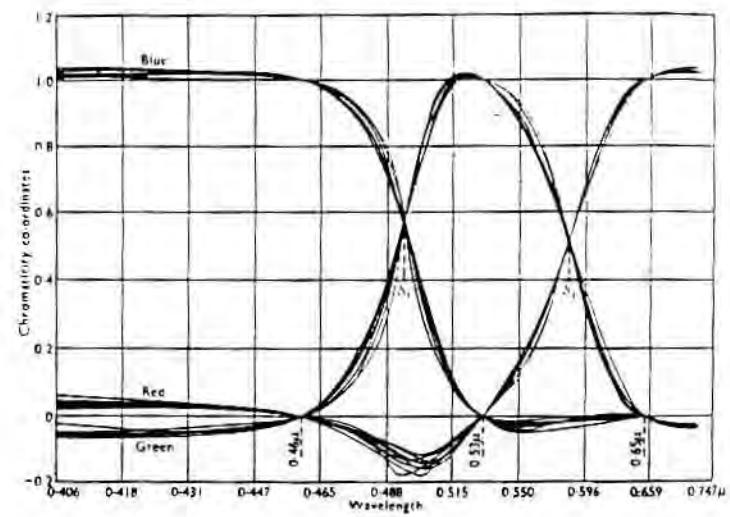
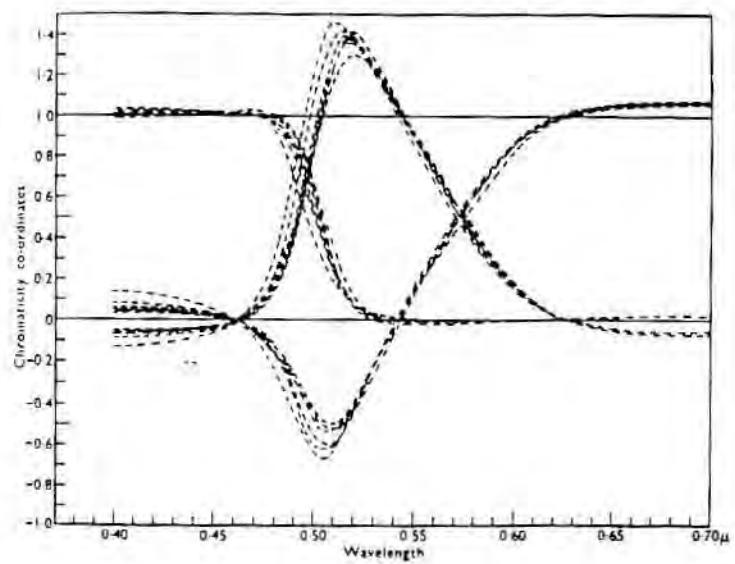


Fig.43. Two early graphs of multiple observers' spectral sensitivity curves. Seven observers as measured by Guild (1931) (above). Ten observers measured by Wright (1928-9).

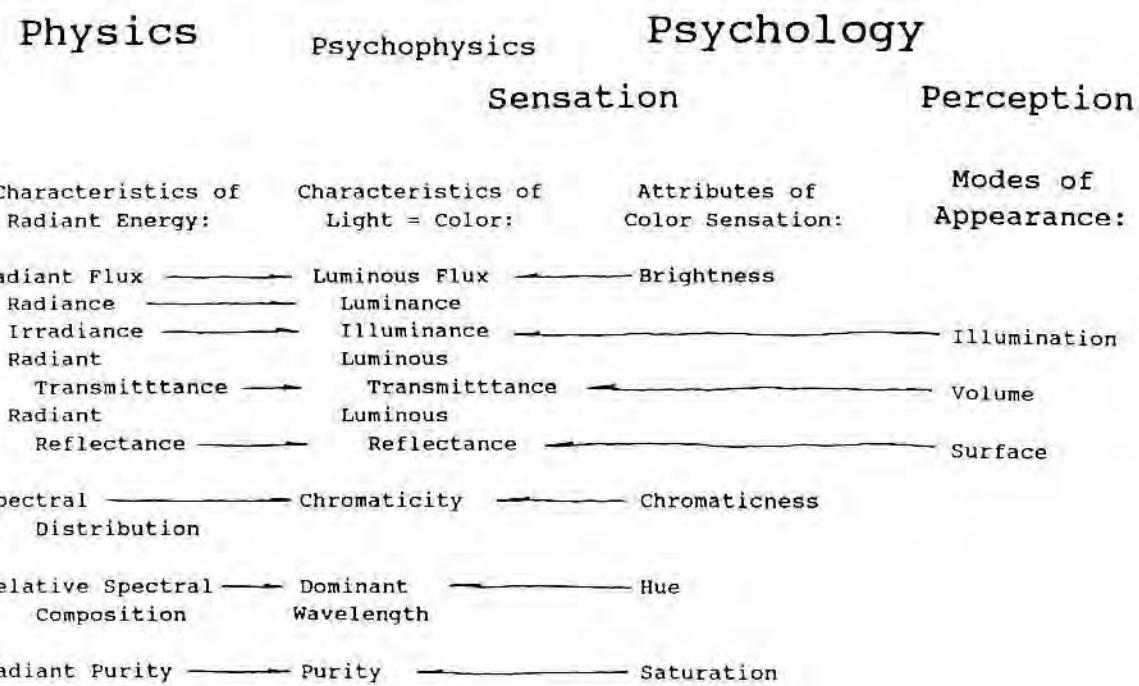


Fig. 44. Psychophysical correlates characteristics of radiant energy in physics, psychophysics, sensation and perception.

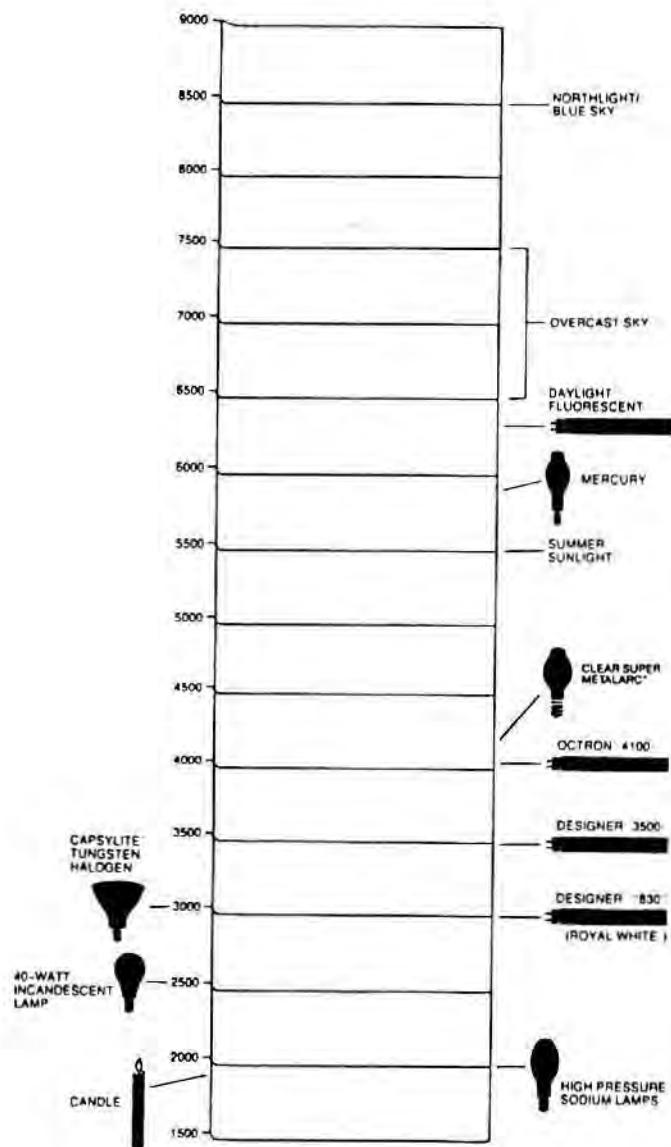


Fig.45. Color temperature of artificial light sources given as black body radiation.

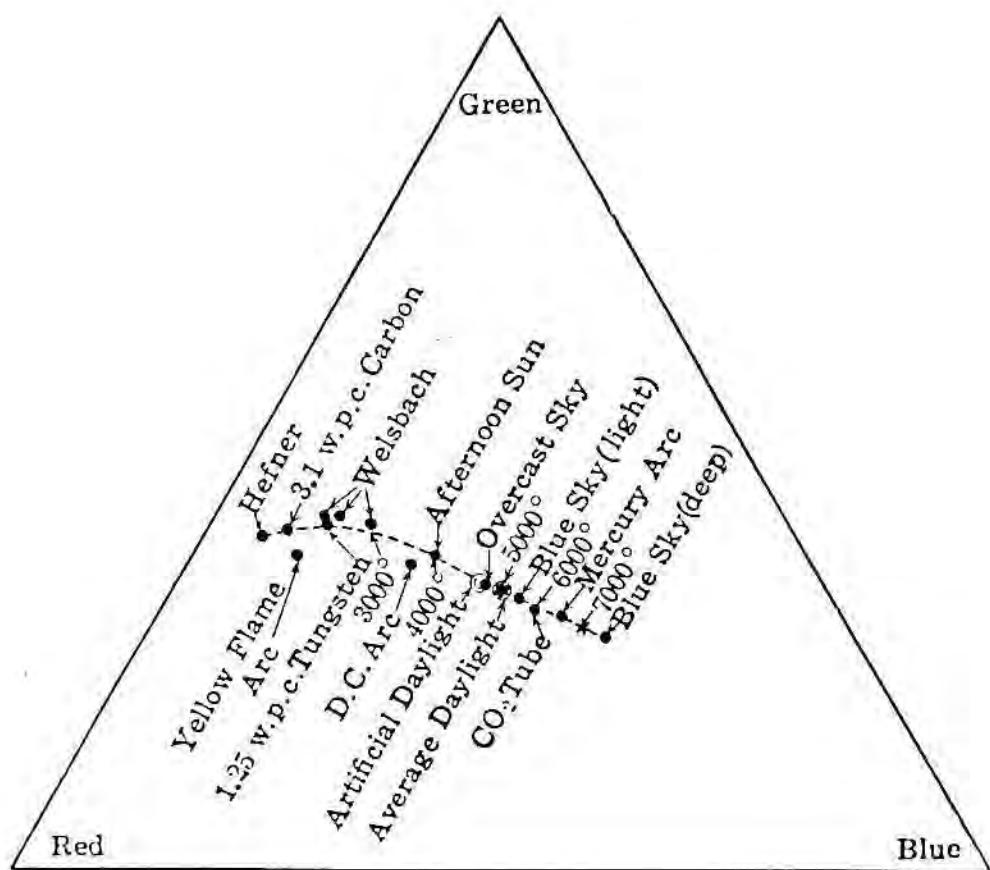


Fig. 46. Color temperature of various light sources given as black body radiation in a Maxwell color triangle. Maxwell triangle is an intermediate precedent between von Helmholtz informed speculation and the mathematical formulation of the CIE (1931) chromaticity diagram.

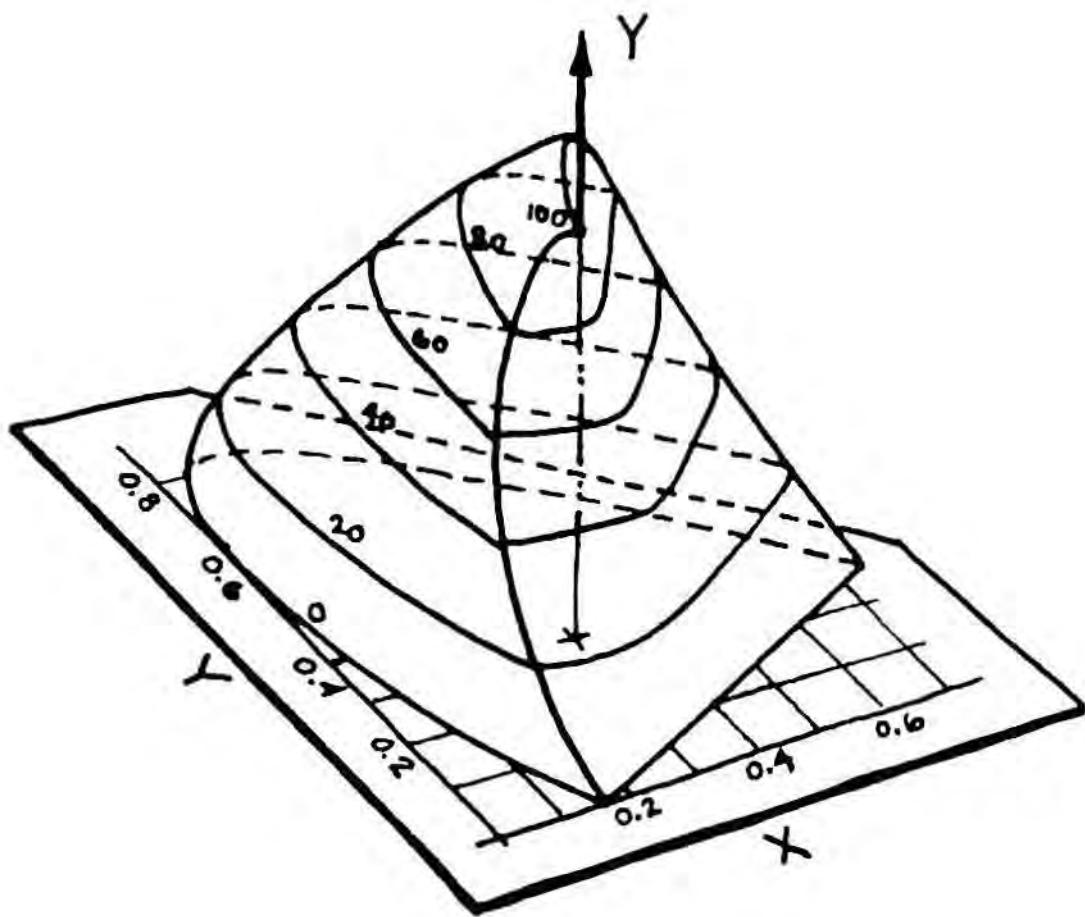


Fig. 47. CIE chromaticity diagram in three dimensions. x-y is the plane of the diagram as it is typically shown in two dimensions.

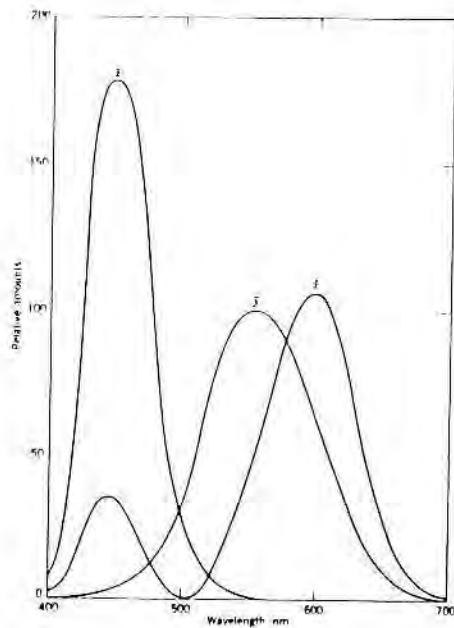
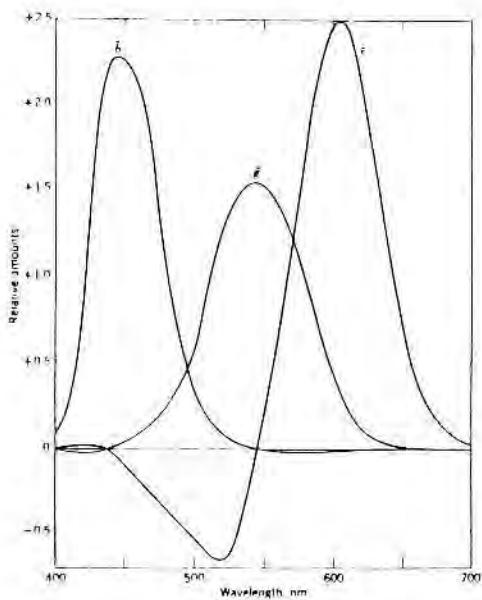


Fig. 48. Spectral distribution curves of a standard observer noted as $(\bar{b}, \bar{g}, \bar{r})$ (above). The mathematical idealization given as $(\bar{z}, \bar{y}, \bar{x})$ (below). Note that negative \bar{r} is expressed as positive \bar{x} . This mathematical sleight of hand is what makes Helmholtz' principle colors into imaginary primaries.

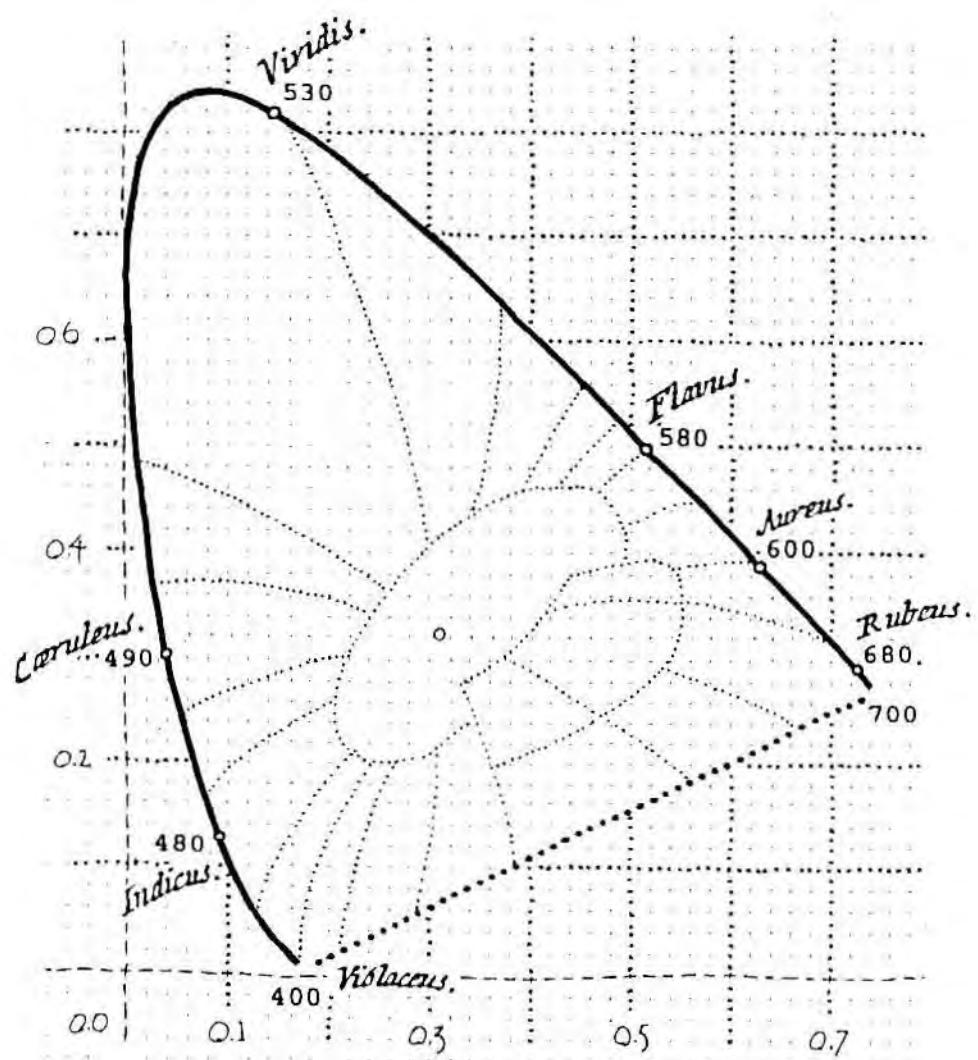


Fig.49. Von Helmholtz' diagram evolved into the CIE (1931) chromaticity diagram, shown above with Newton's "primary" color names in their relative locations.

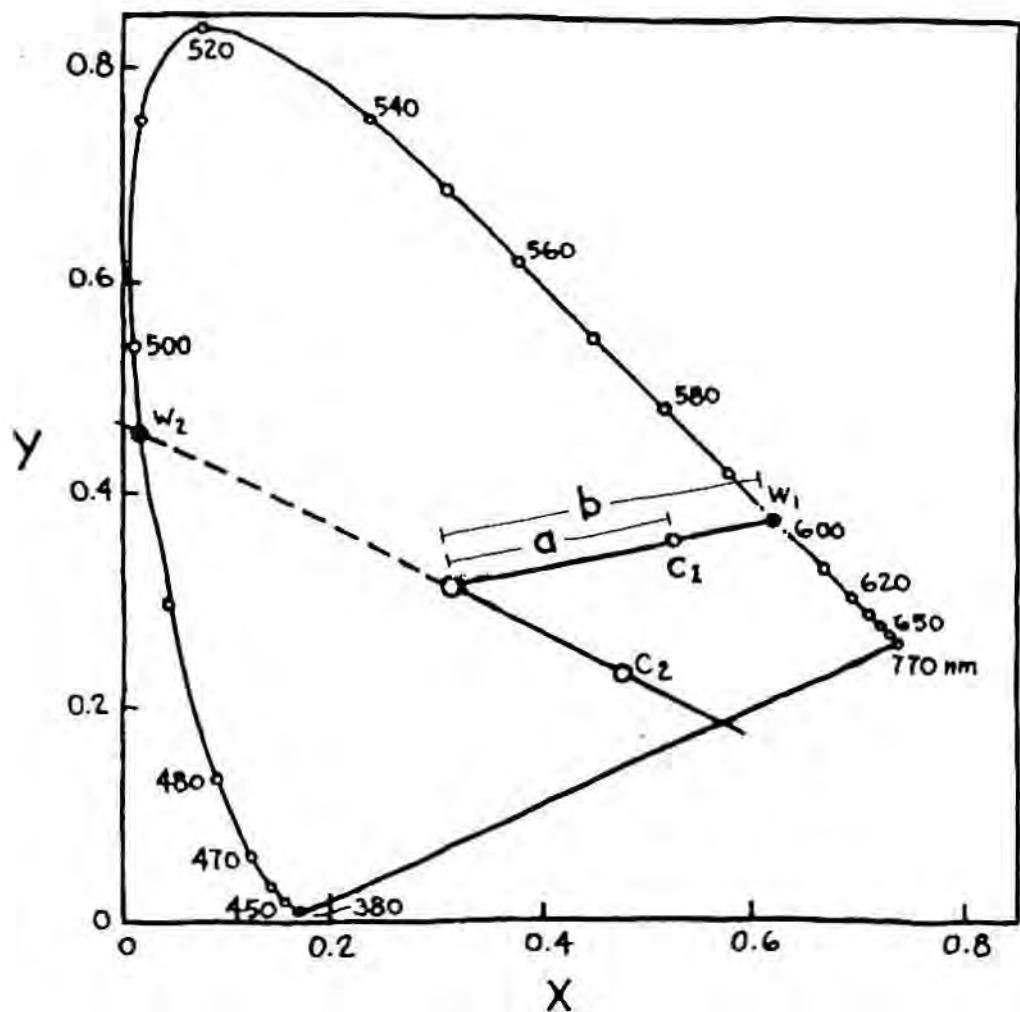


Fig.50. Diagrammatic definition of dominant wavelength, complimentary dominant wavelength and purity. If C_1 is the target color W_1 is its dominant wavelength. If C_2 is the target color W_2 its complimentary dominant wavelength. The purity of target color C_1 is the ratio a/b . Note that a and b are distance measures given in a Euclidean plane space.



Fig.51. Claude Monet *Self-portrait*, 1886 (private collection).
This self-portrait is slightly less emotionally dark than it
appears here.



Fig.52. *Grainstack (End of Summer)*, 1890-1891. Monet painted at least 30 paintings in the grainstack series including two subtitled *End of Summer*. This is the canvas analyzed in section five, from The Art Institute of Chicago.



Fig.53. *Grainstacks (End of Summer)*, 1890-1891 (Musee d'Orsay), Paris. This version is not discussed in the text.



Fig.54. View from Monet's second studio circa 1905 originally published in *L'Art et les Artistes*, (Dec. 1905:20). A photographic view of the *clos Morin* field adjacent to Monet's house at Giverny.



Fig.55. *Grainstack in Sunlight*, 1891 (Kunsthaus, Zurich).
Wassily Kandinsky attributes his idea for non-objective art
to a viewing of this painting.



Fig. 56. Georges Seurat, *Une Baignade à Asnières*, 1884 (National Gallery, London). Seurat's first pointillist painting completed when he was twenty-five.



Fig. 57. Jacob Christoph le Blon portrait of Cardinal de Fleury. An early "color separation," Gage notes that le Blon's commercial enterprise failed because the process required extensive hand finishing.

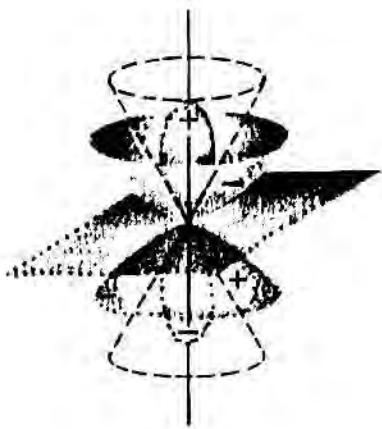
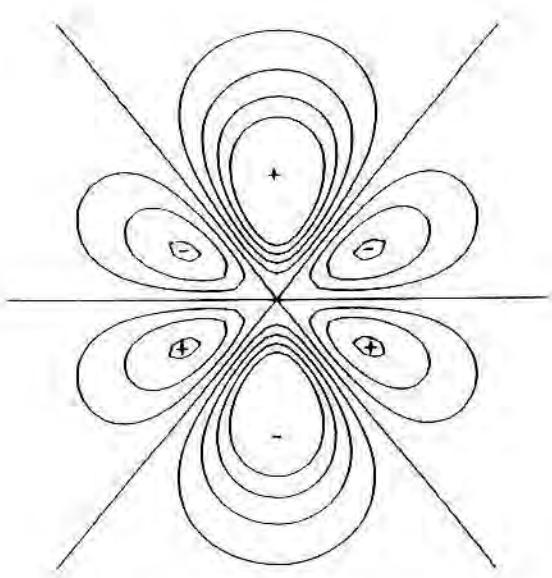


Fig.58. "Shells" of electrons.

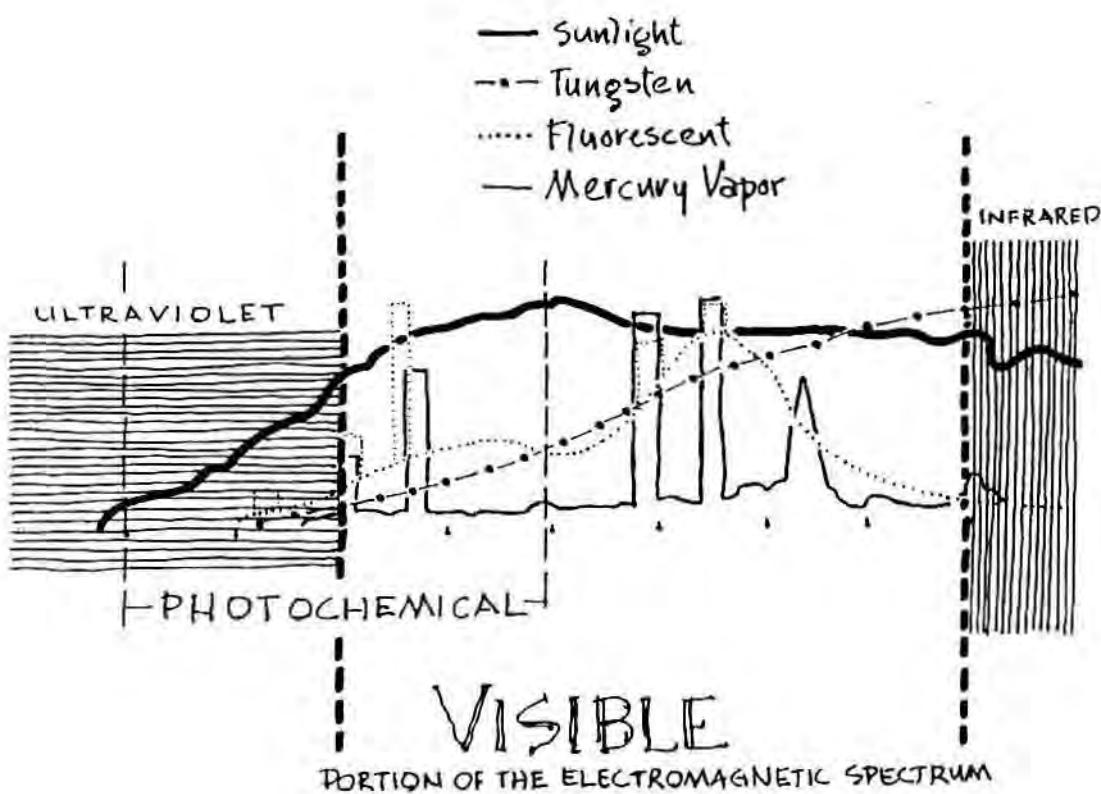


Fig. 59. A portion of the electromagnetic spectrum showing the range of photographic and human visual processing and the spectral distribution of artificial light sources relative to sunlight.

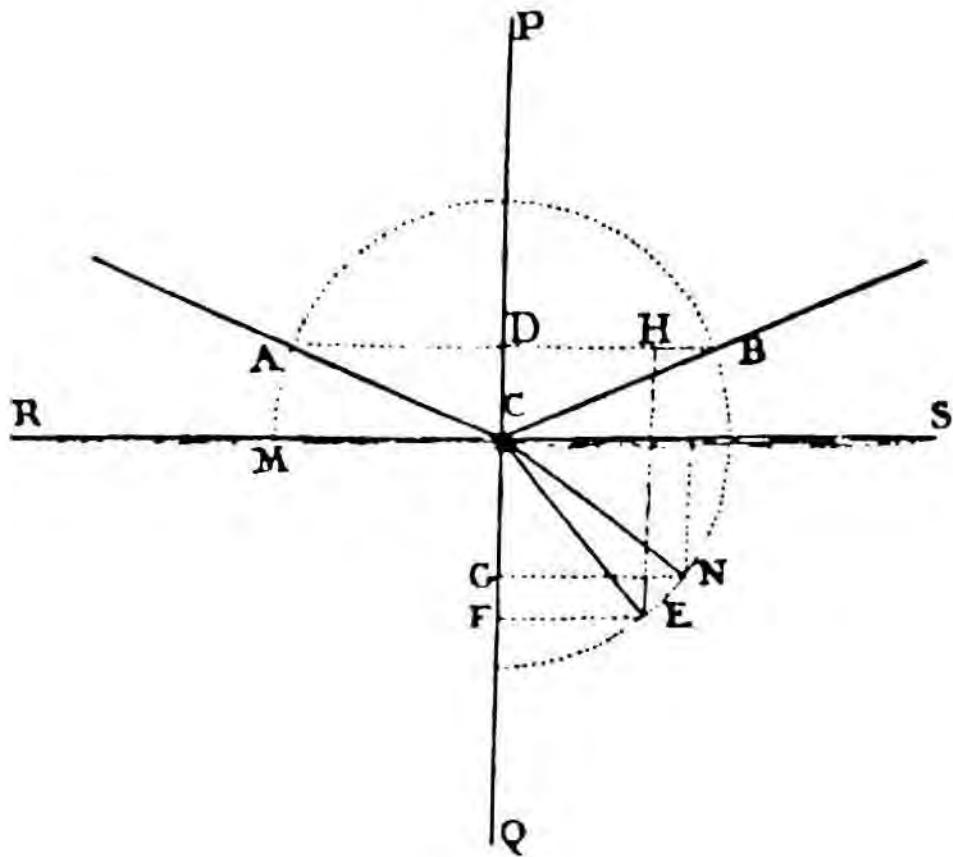


FIG. 1.

Fig. 60. Newton's diagram from the Opticks illustrating the geometry of reflection and refraction. (A) is incident light, (B) is reflected, (P) is normal to the surface. (E) is refracted, (N) is the boundary between reflection and refraction.

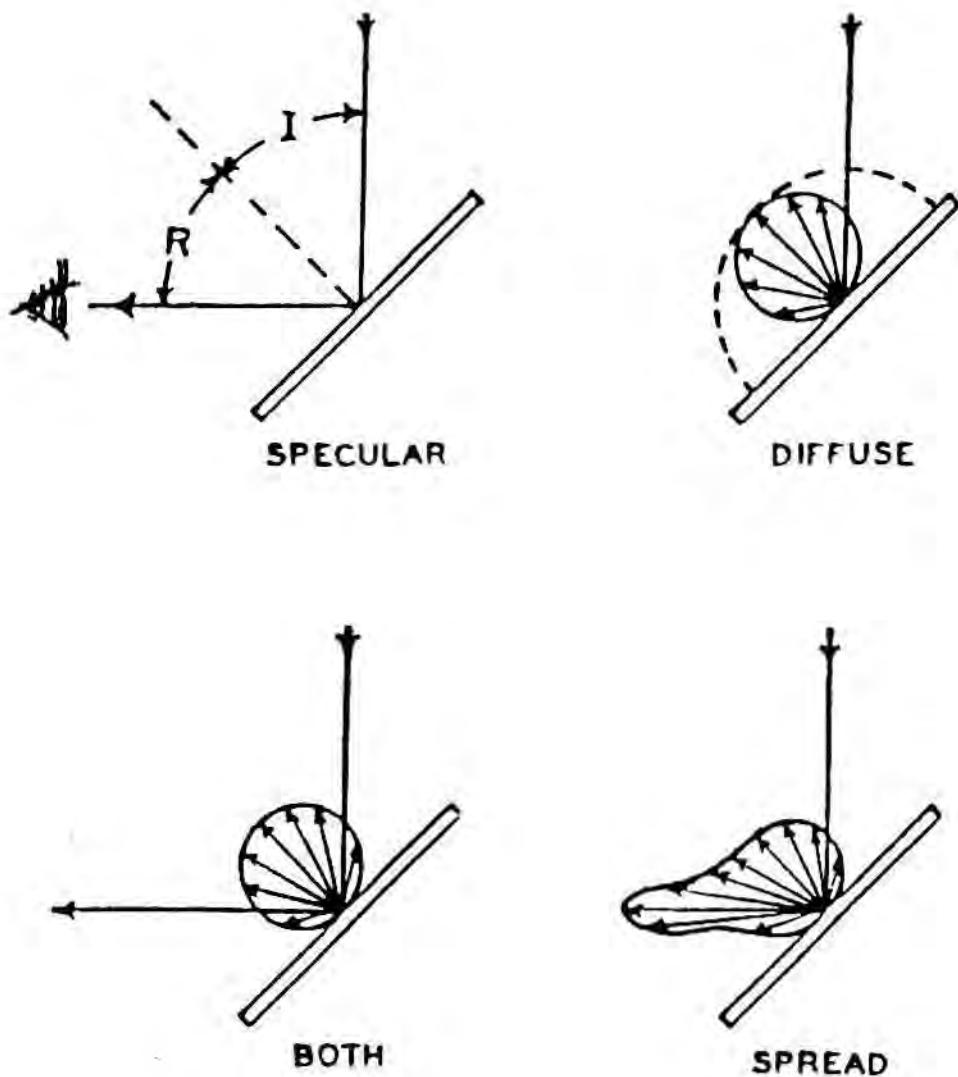


Fig. 61. Diagrammatic definition of specular and diffuse reflection.

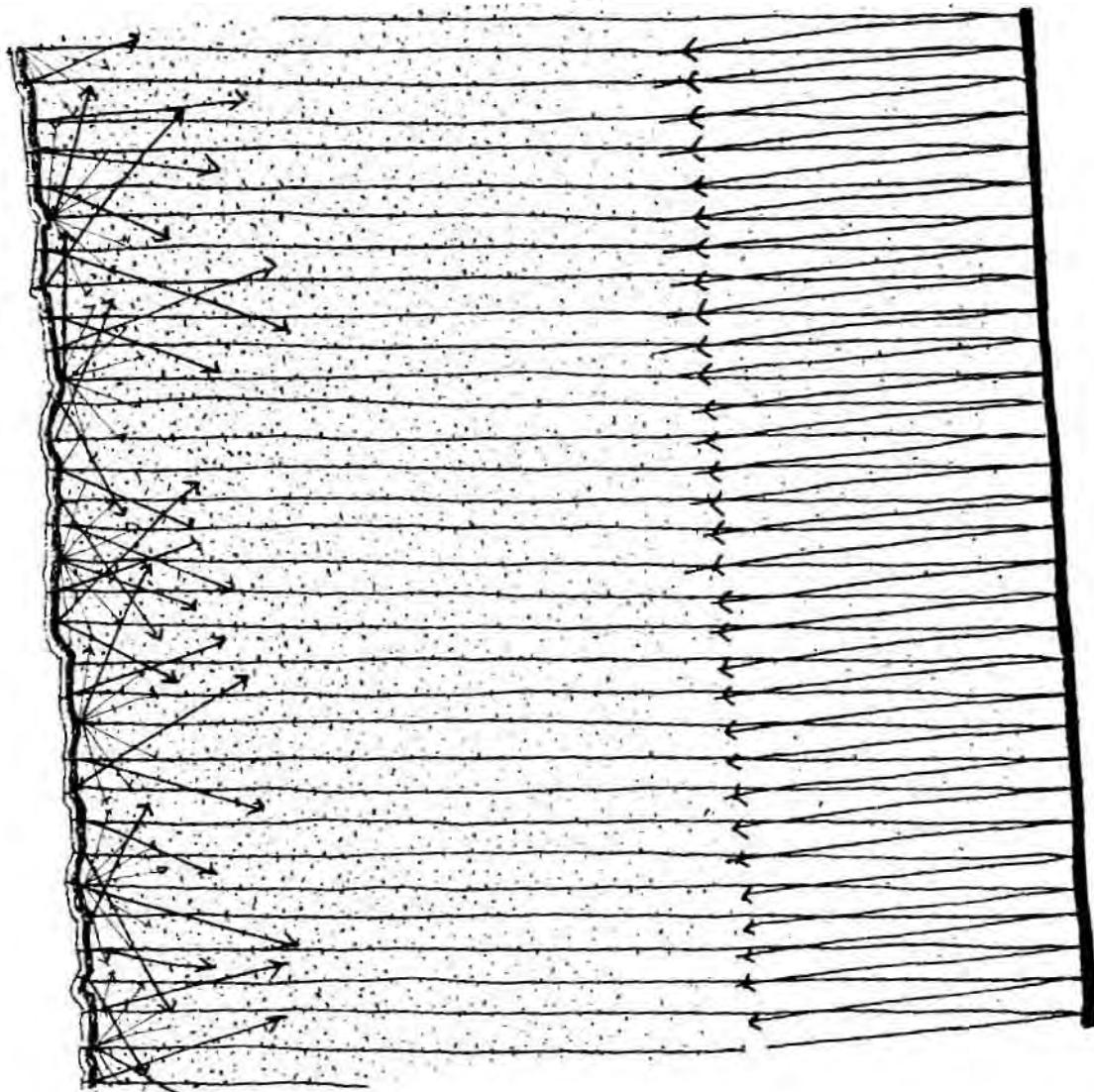


Fig. 63. Diffuse reflected light (left), and specular reflected light (right).

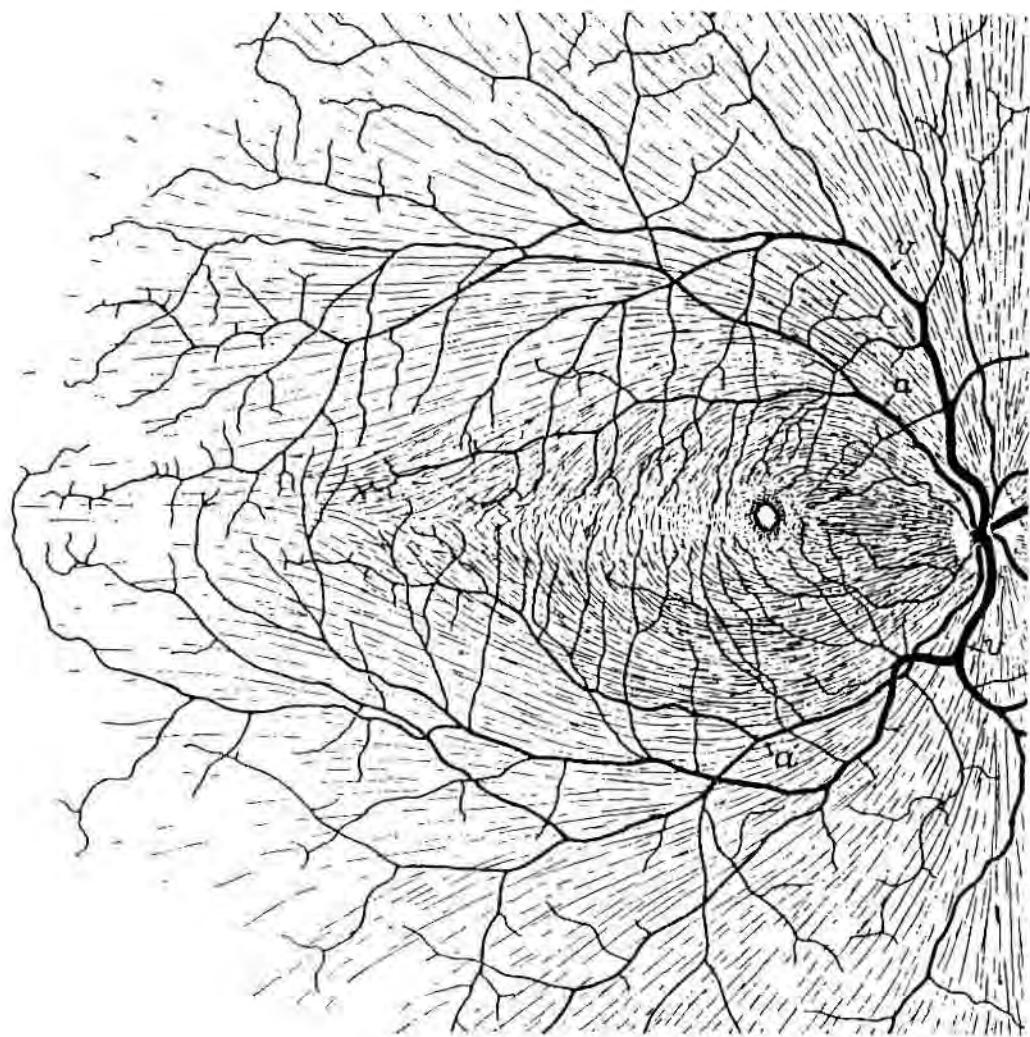


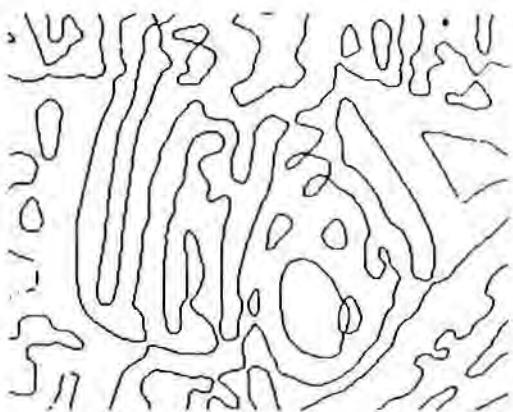
Fig.65. Retina of adult Rhesus Macaque showing blood vessels and retinal fibers.



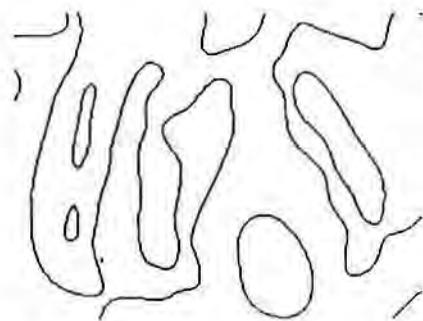
(a)



(b)



(c)



(d)

Fig.66. David Marr's theory of edge detection. (a) is a continuous tone photograph of a Henry Moore sculpture. (b-d) are "convolved" images using three size tuned filters that operate in the human fovea. Lines indicate "zero-crossings" which are the second differential of brightness from the visual array.

-1	+1
----	----

$$\partial/\partial x$$

+1
-1

$$\partial/\partial y$$

+1	-2	+1
----	----	----

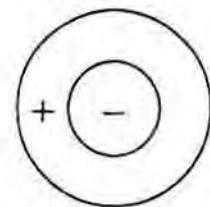
$$\partial^2/\partial x^2$$

+1
-2
+1

$$\partial^2/\partial y^2$$

-1	+1
+1	-1

$$\partial^2/\partial x \partial y$$



$$(\partial^2/\partial x^2 + \partial^2/\partial y^2)$$

Fig.67. Configurations of differential operators. The circularly symmetric form is the lowest-order Laplacian isotropic operator, which is what Marr used to derive edges from brightness.

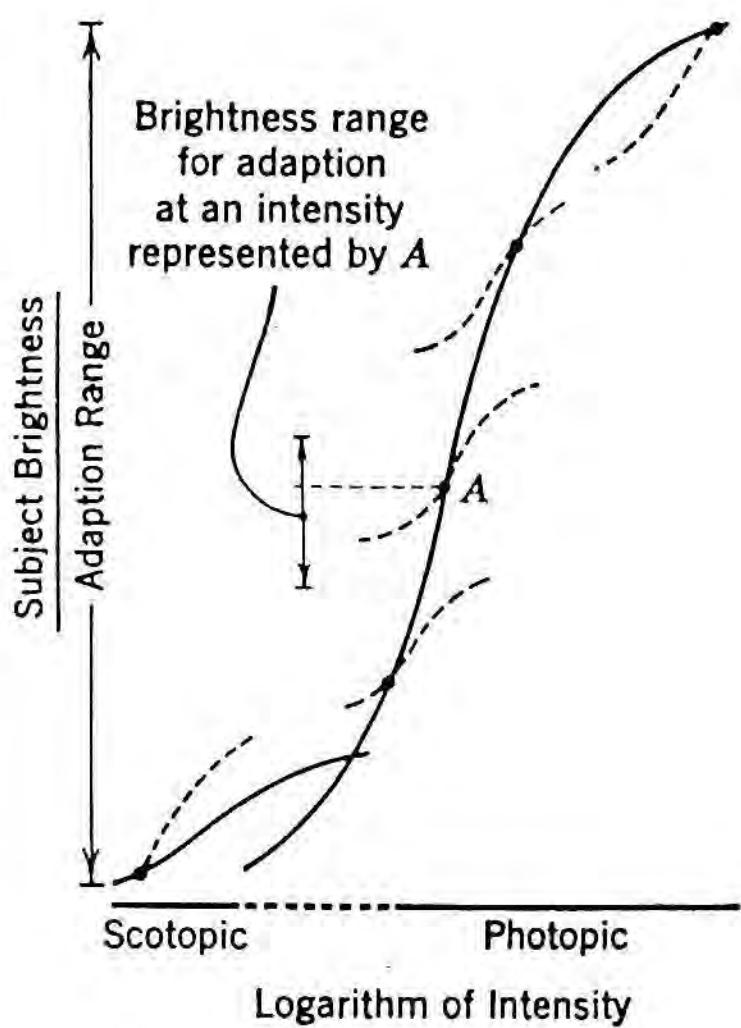


Fig. 68. Relation of global brightness to local adaptation and the ranges of scotopic, mesopic, and photopic adaptation.

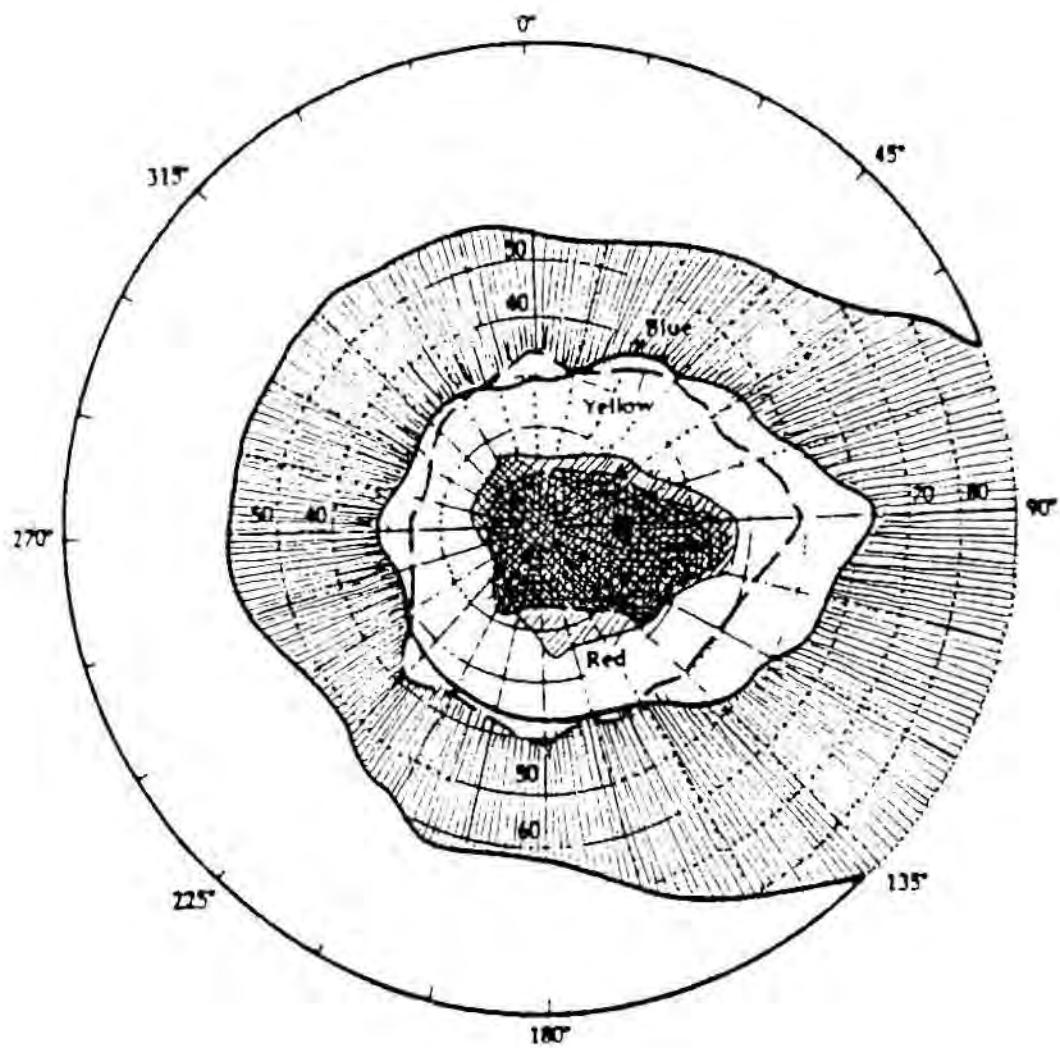


Fig. 69. Right eye, polar representation, of the limits of chromatic sensitivity.

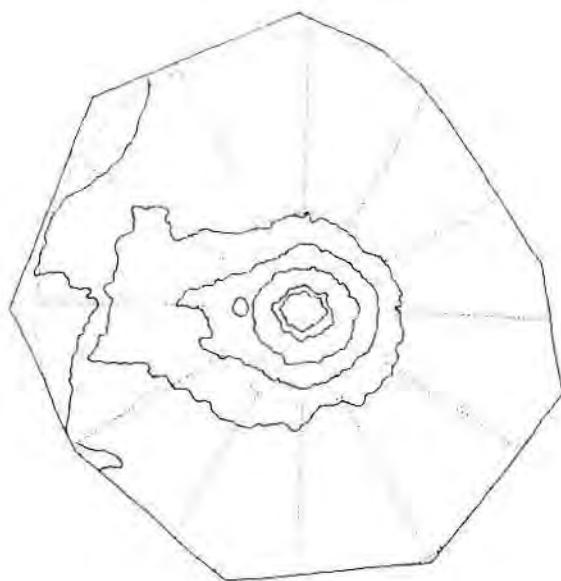
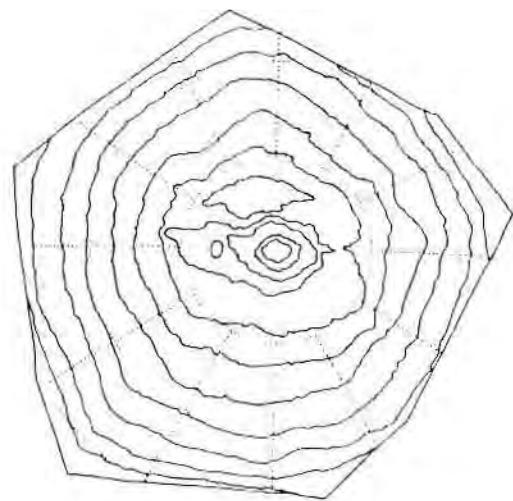


Fig. 70. The density of rods (top) and cones (bottom) in the human retina (left eye). Densities decrease from the fovea outwards. Note the relatively even density of rods in the peripheral retina.

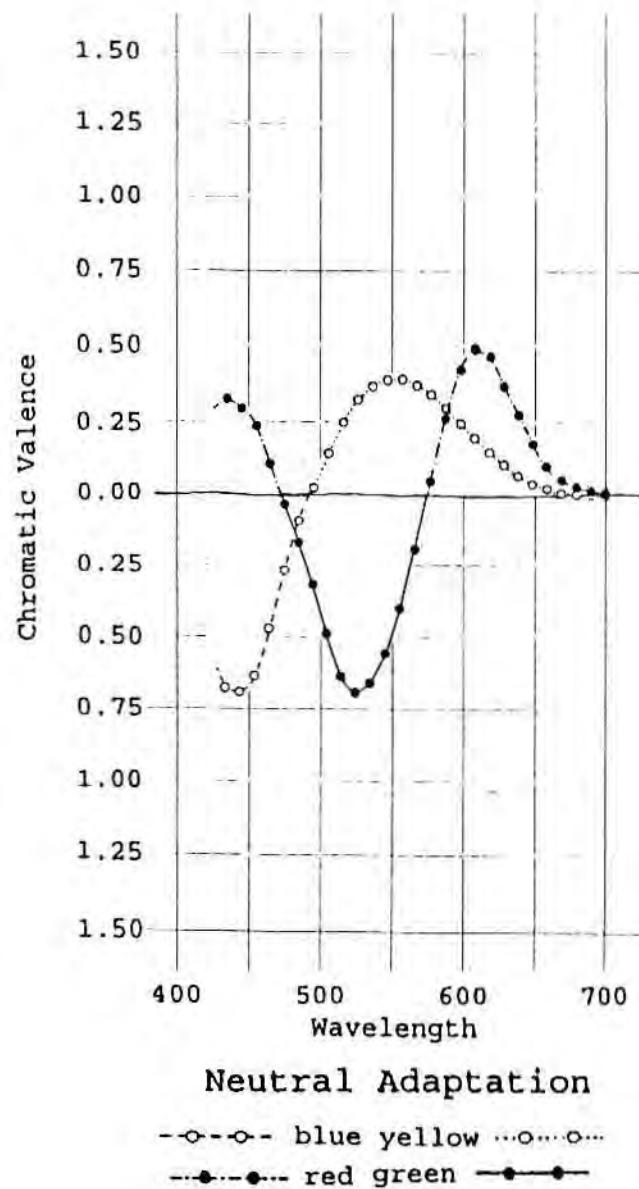
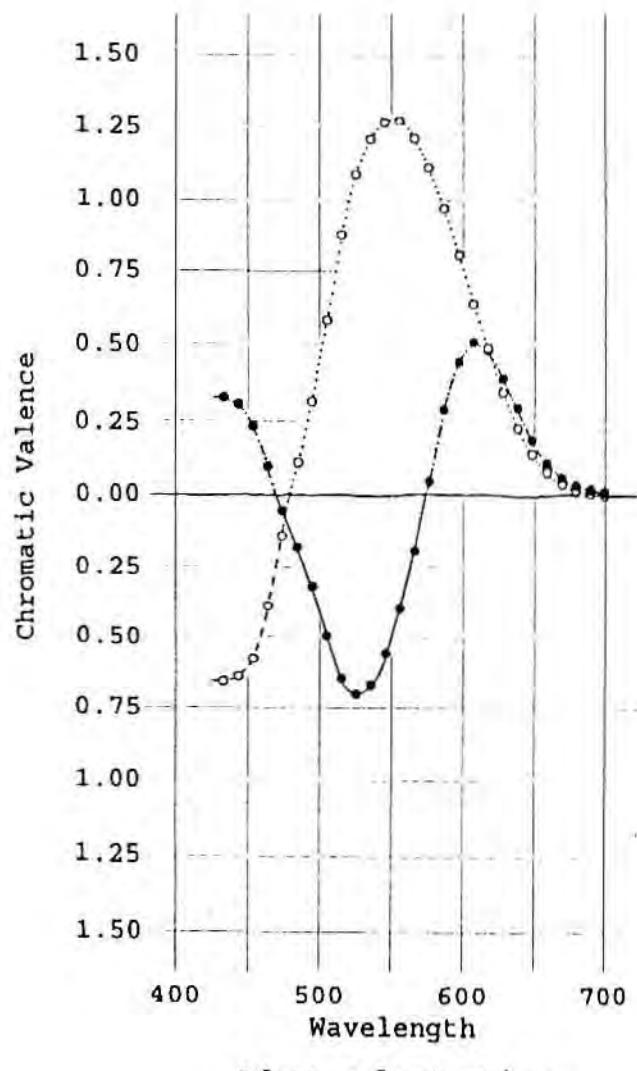


Fig. 71. Chromatic adaptation.



Blue Adaptation

--o-- blue yellow ...o...

--●-- red green ●●●

Fig. 72. Chromatic adaptation.

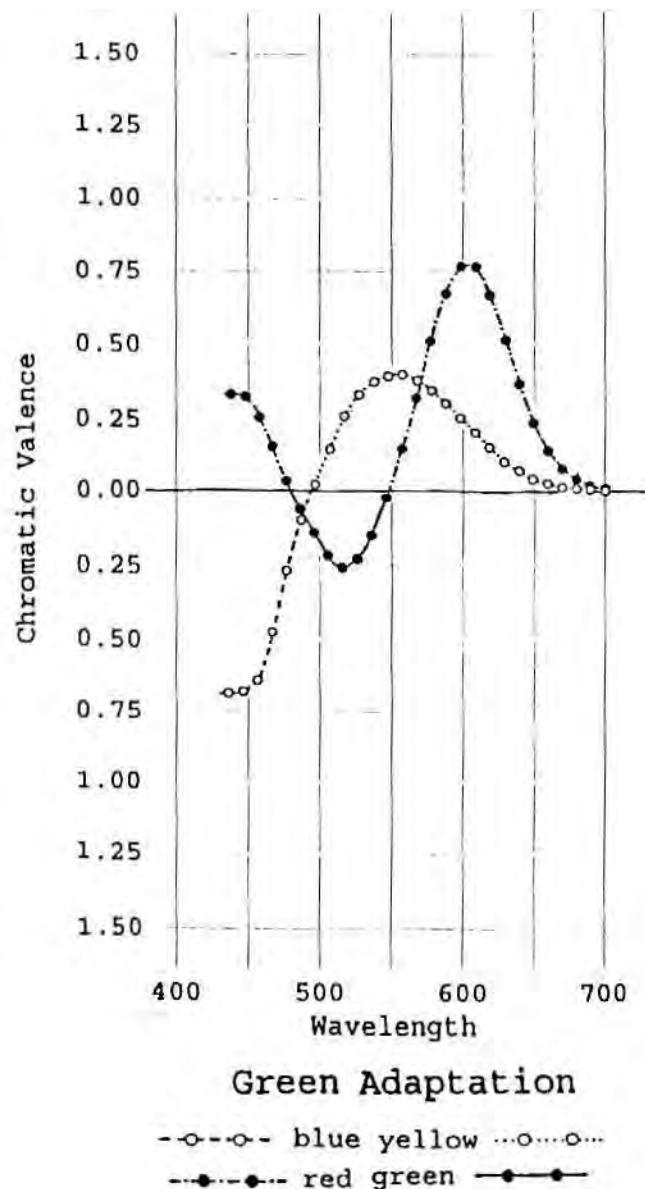


Fig. 73. Chromatic adaptation.

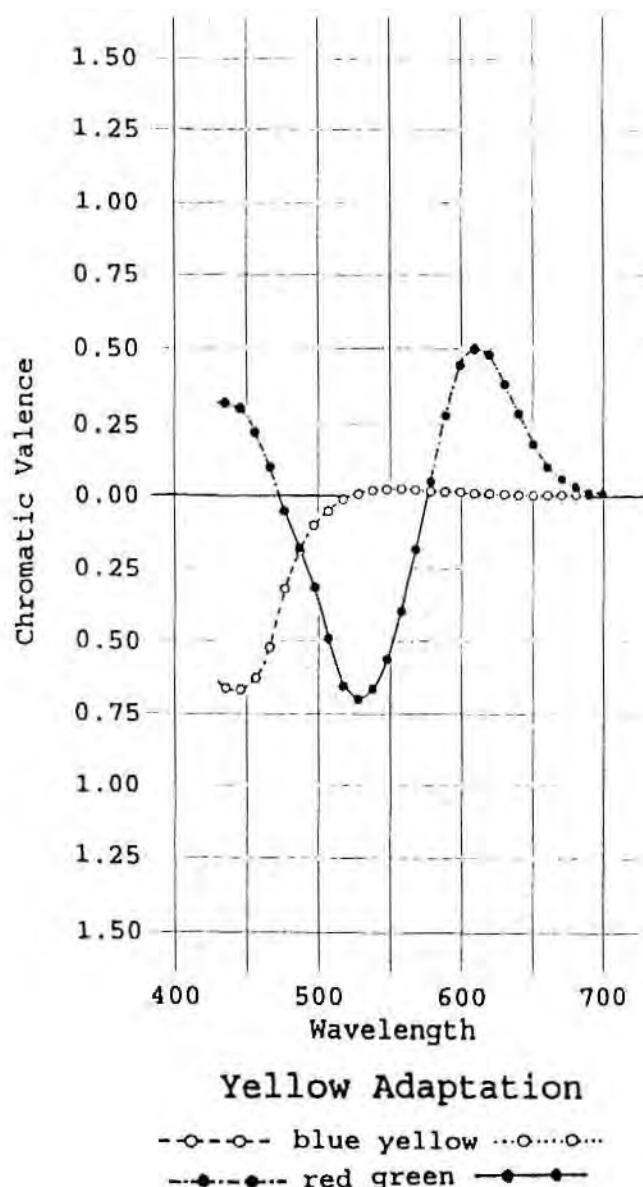


Fig. 74. Chromatic adaptation.

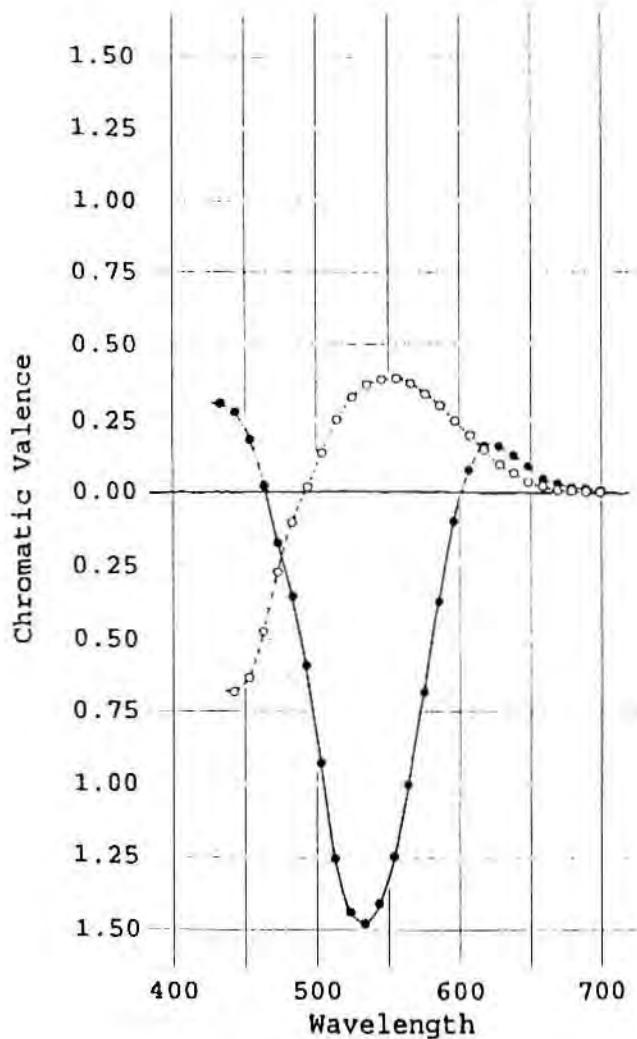


Fig. 75. Chromatic adaptation.

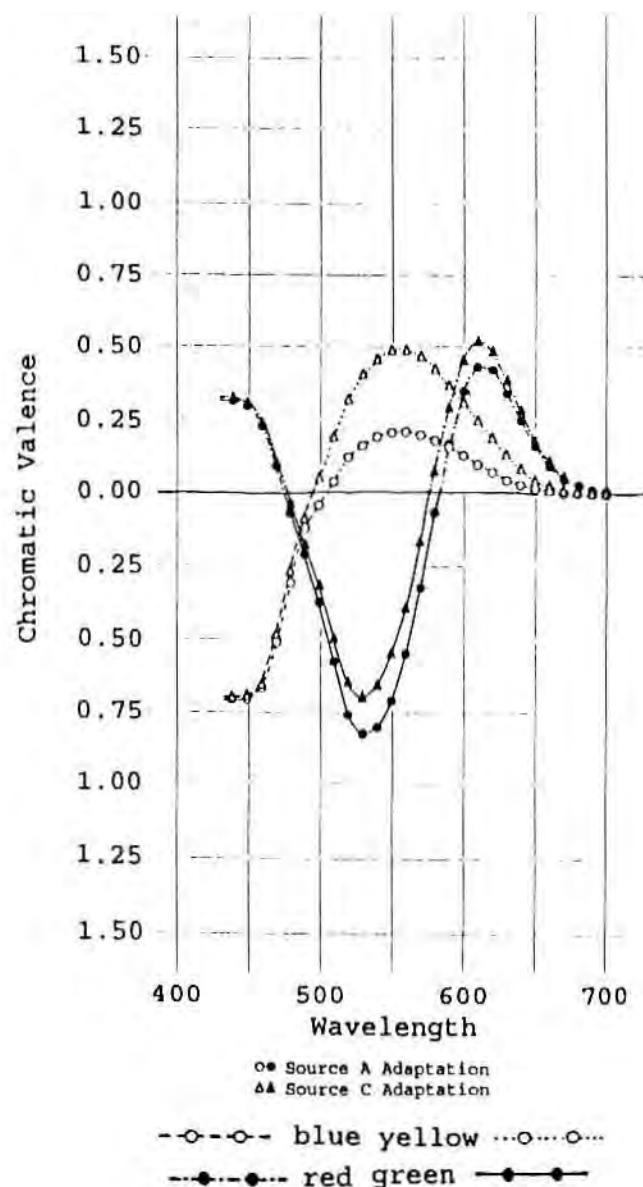


Fig. 76. Chromatic adaptation.

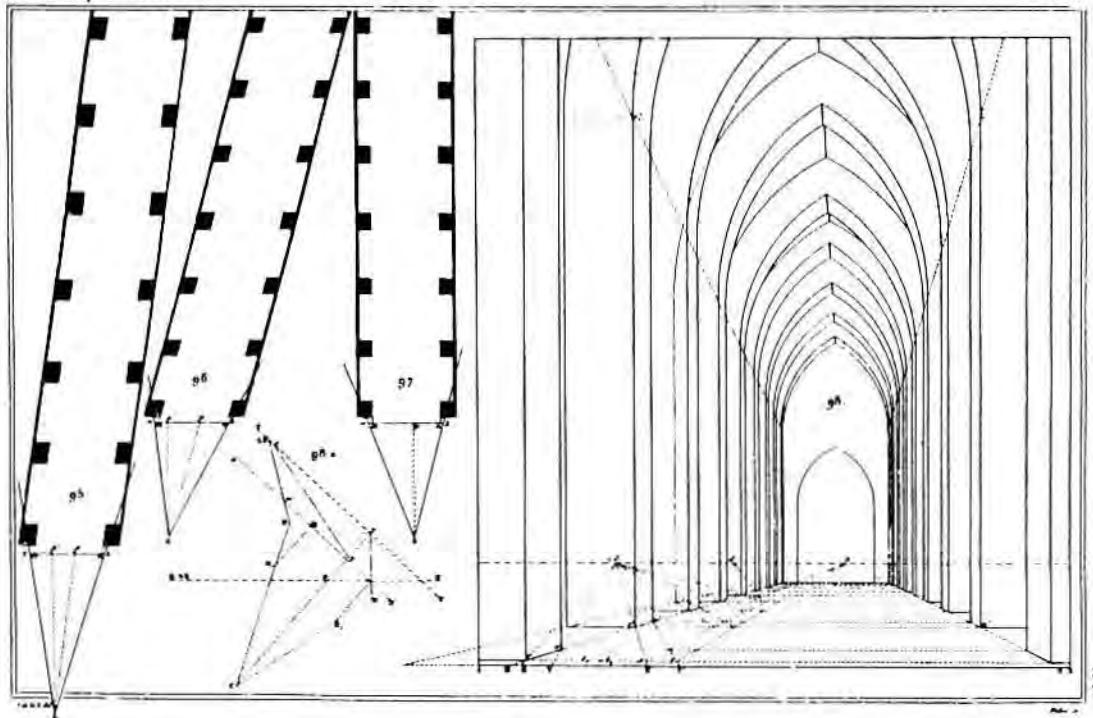


Fig. 77. The robustness of perspective requires that the observer simultaneously perceives the orientation of the surface of the representation and the vantage point of the virtual space. The drawing on the left shows how viewers would reconstruct plans from correct (97) and "incorrect" (95, 96) vantage points. Original drawing from La Gournerie, *Traité de perspective linéaire*, 1884; plate 14.

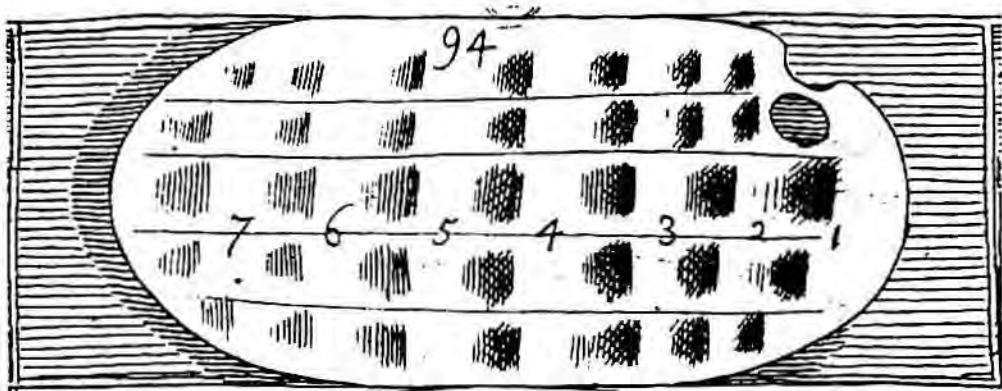


Fig. 78. A painter's palette from Hogarth's The Analysis of Beauty (1753).

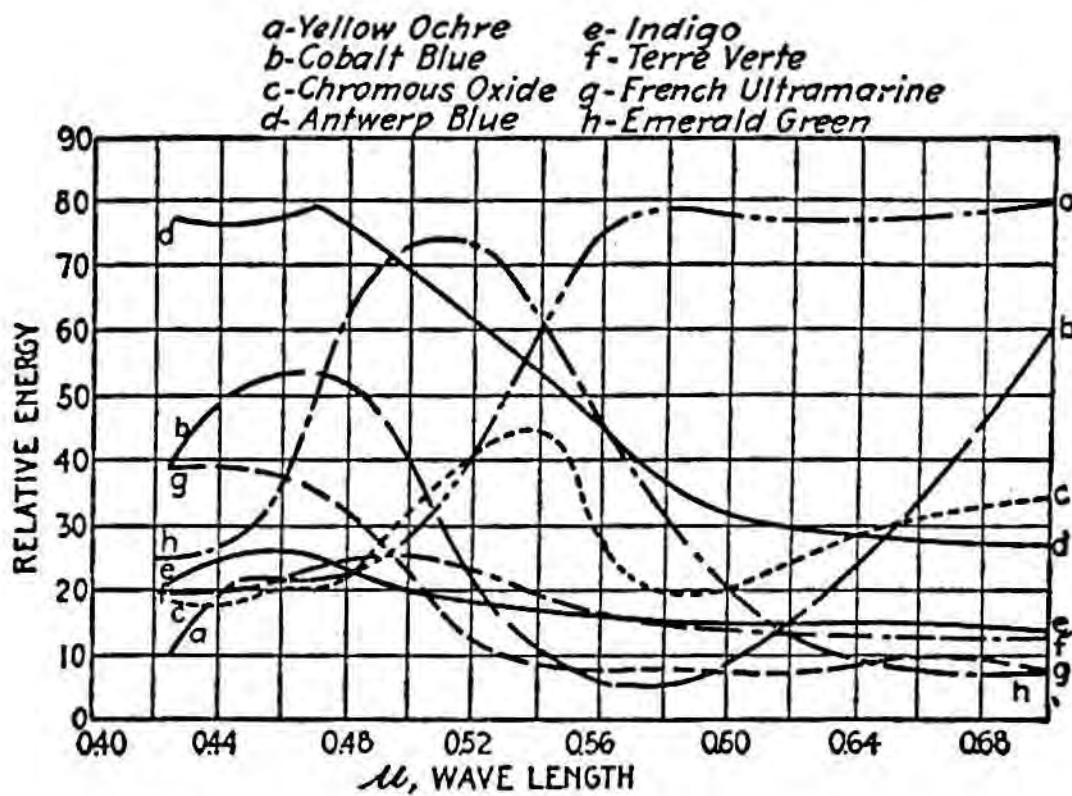


Fig. 79. Spectral analyses of pigments. Something close to (b) and (h) were probably used by Monet.

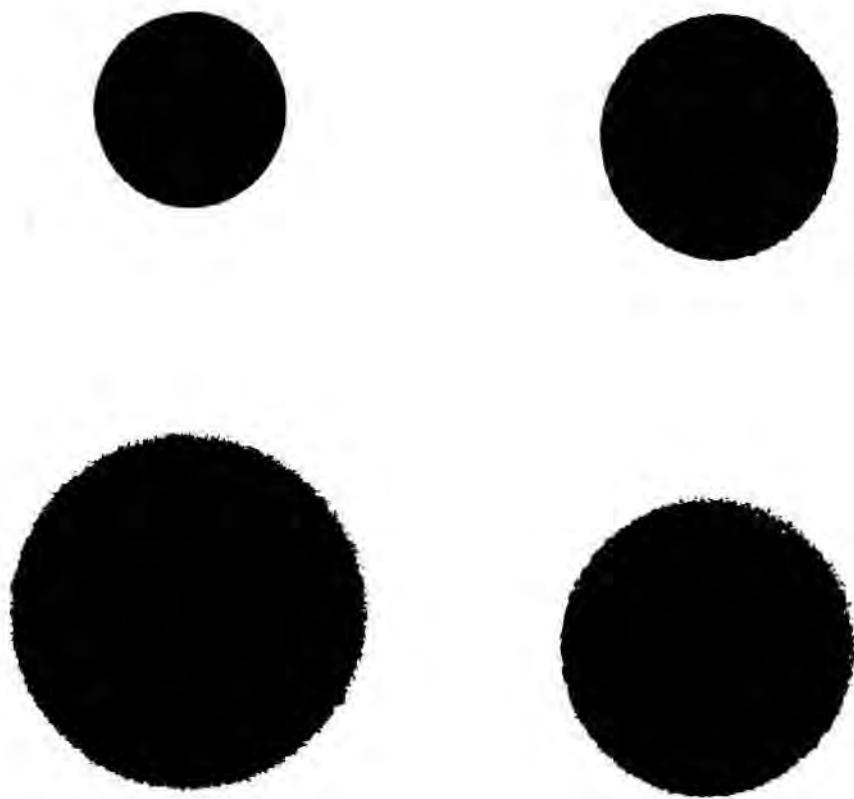


Fig. 80. Evans' demonstration dots.

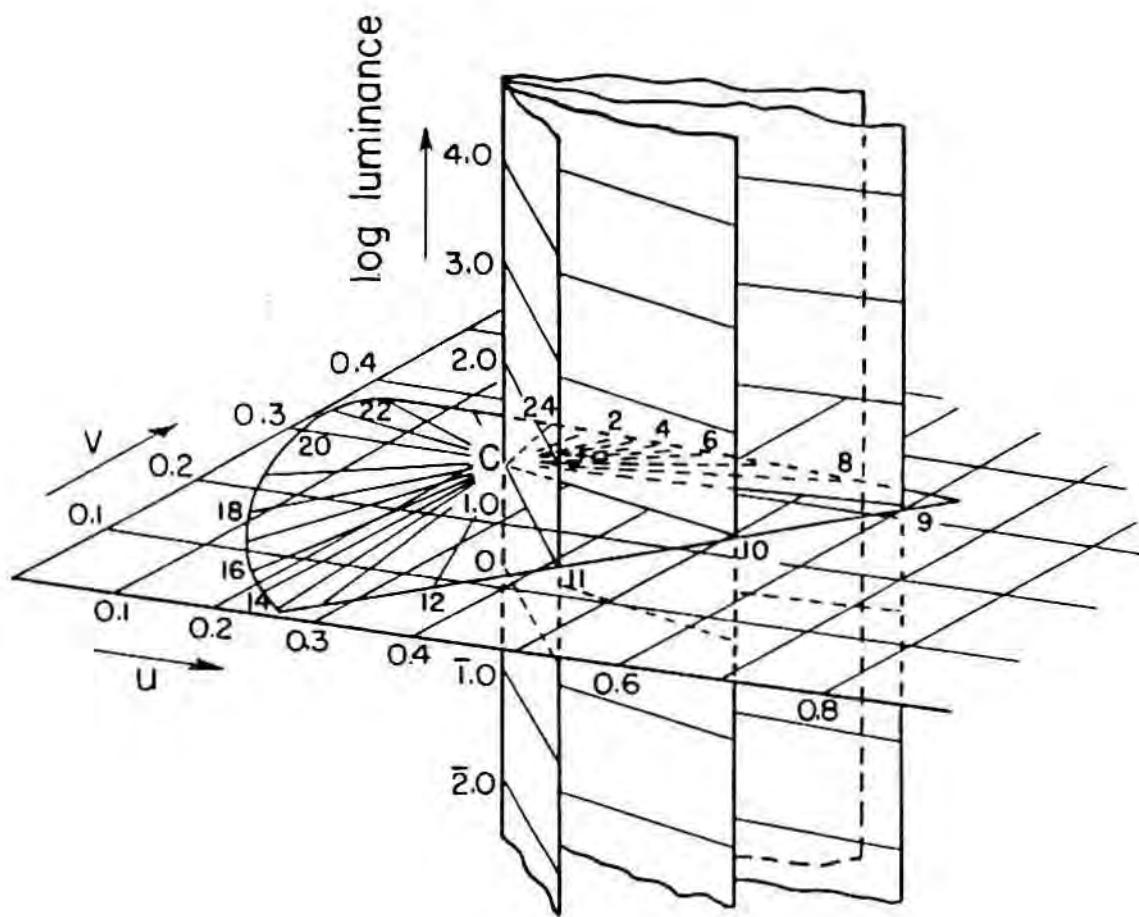


Fig. 81. The log of luminance shown in a perspective view. The horizontal planes of the chromaticity diagram are of identical size which indicates that this is a space of self-luminous and not object colors.

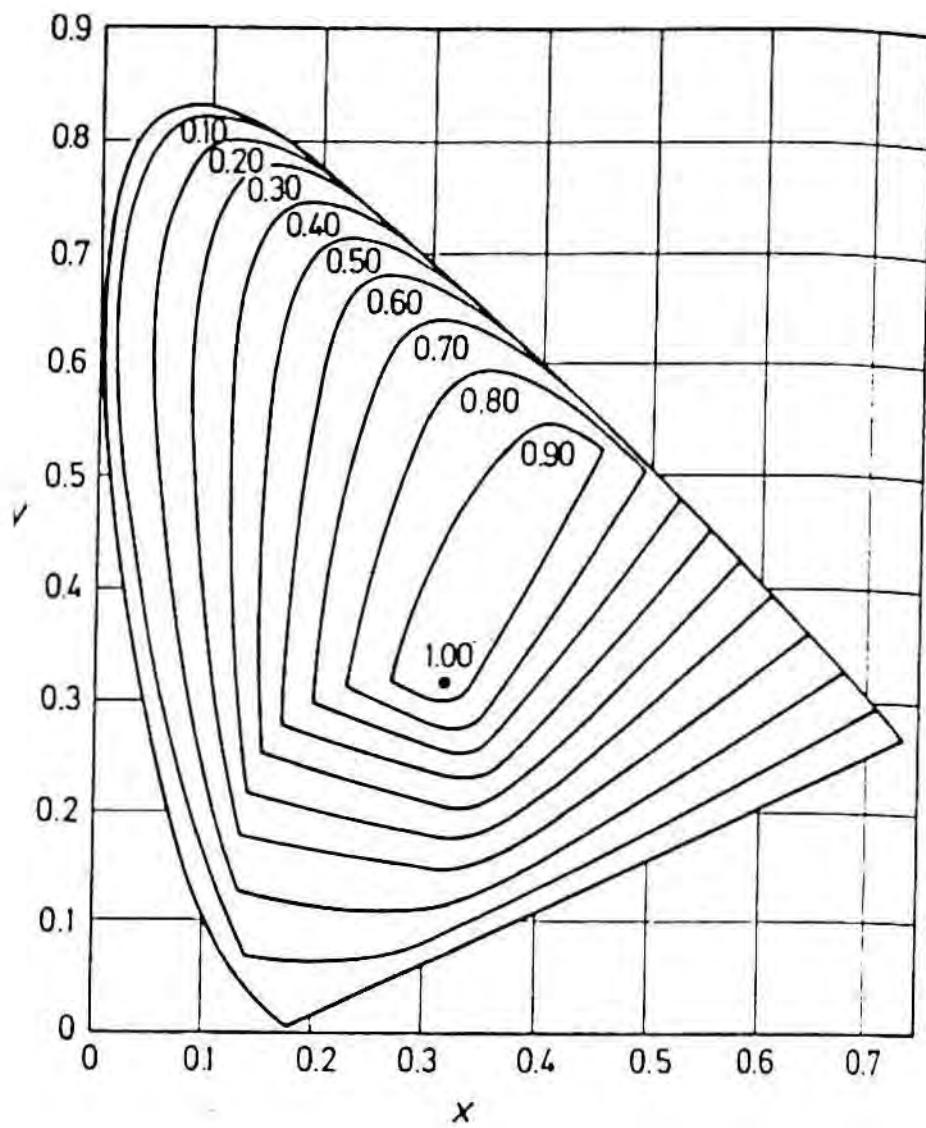


Fig. 82. Layering of spectrum loci for object colors at different levels of luminance, photopically adapted eye.

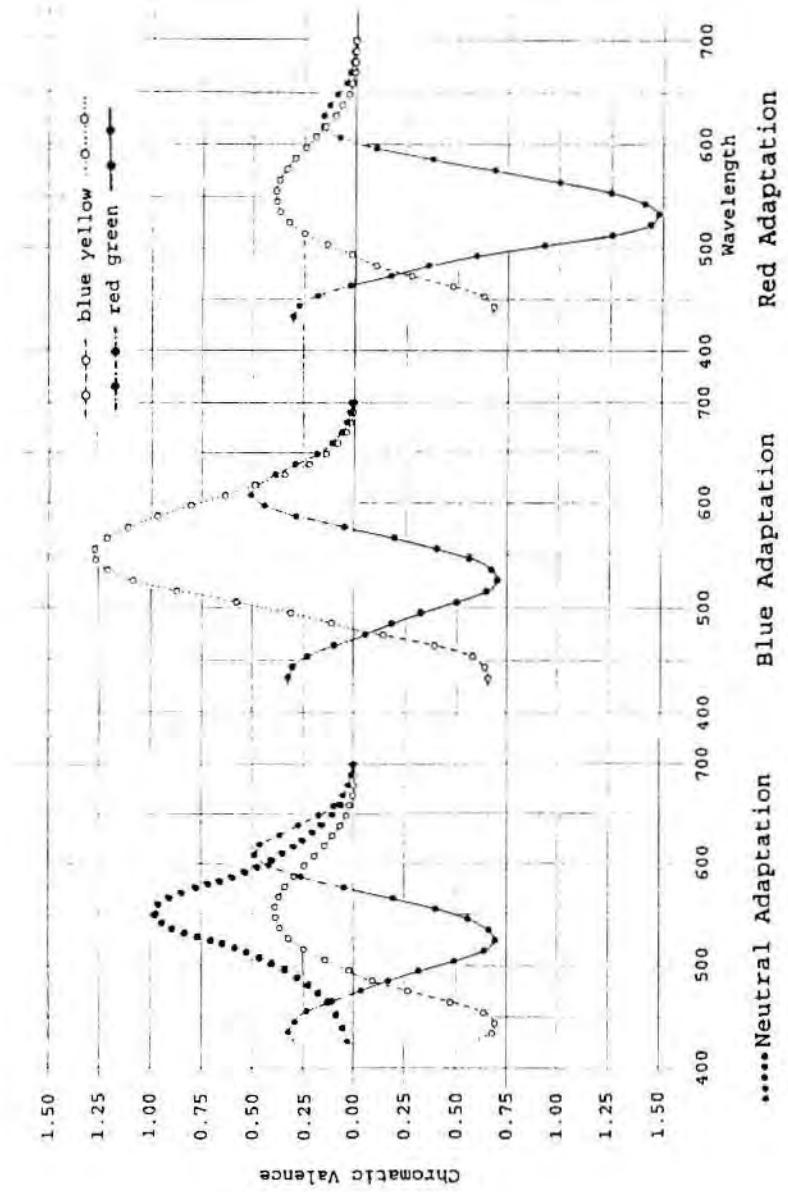


Fig. 83. Comparison of the magnitude of white, neutral adapted to yellow blue adapted and green red adapted.

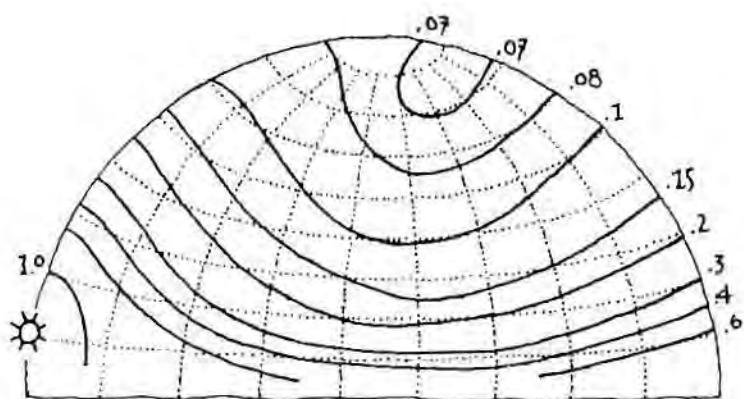
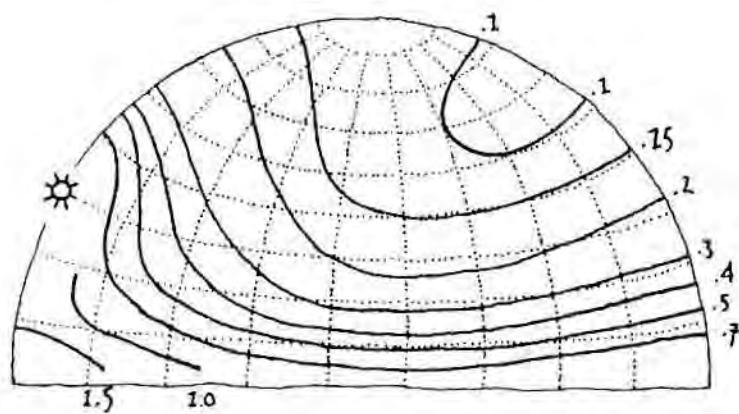


Fig. 84. Smoothed isograms of daytime brightness for a highly transparent atmosphere.

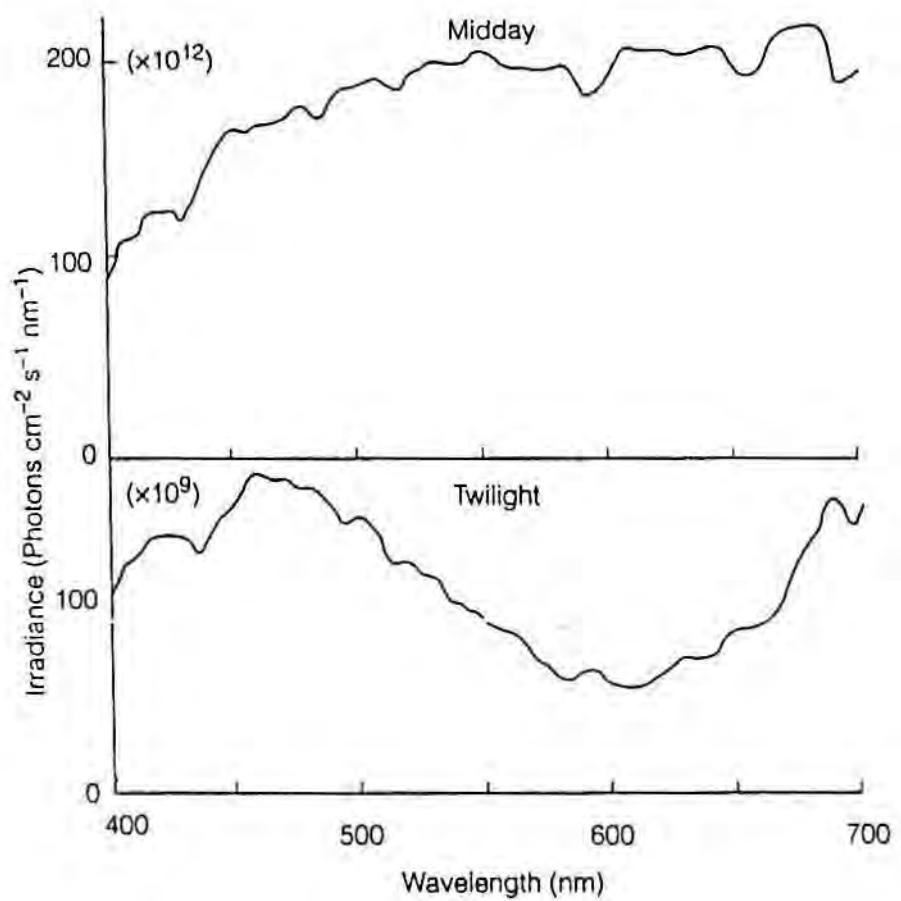


Fig. 85. Spectral composition of illuminance. Data from Enewetak Atoll, Summer 1970.

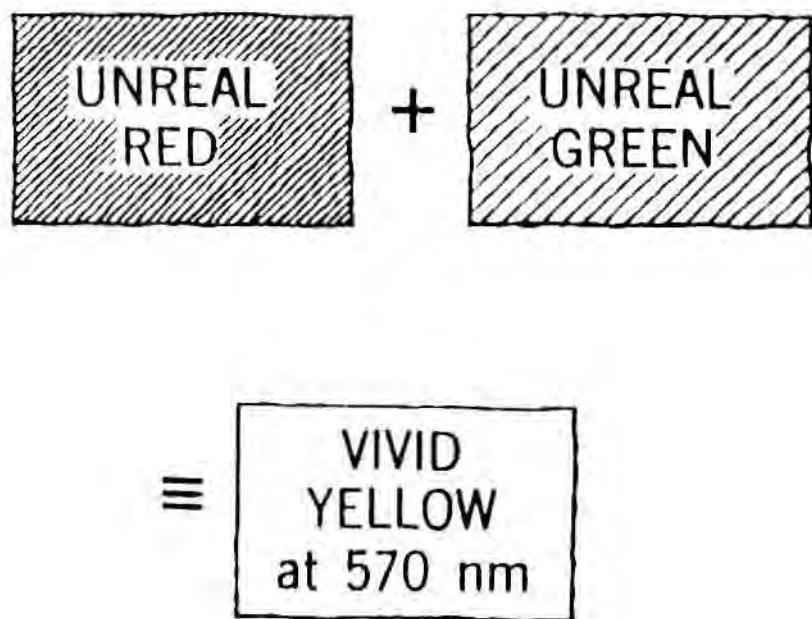


Fig. 86. Schematic of additive color mixing.

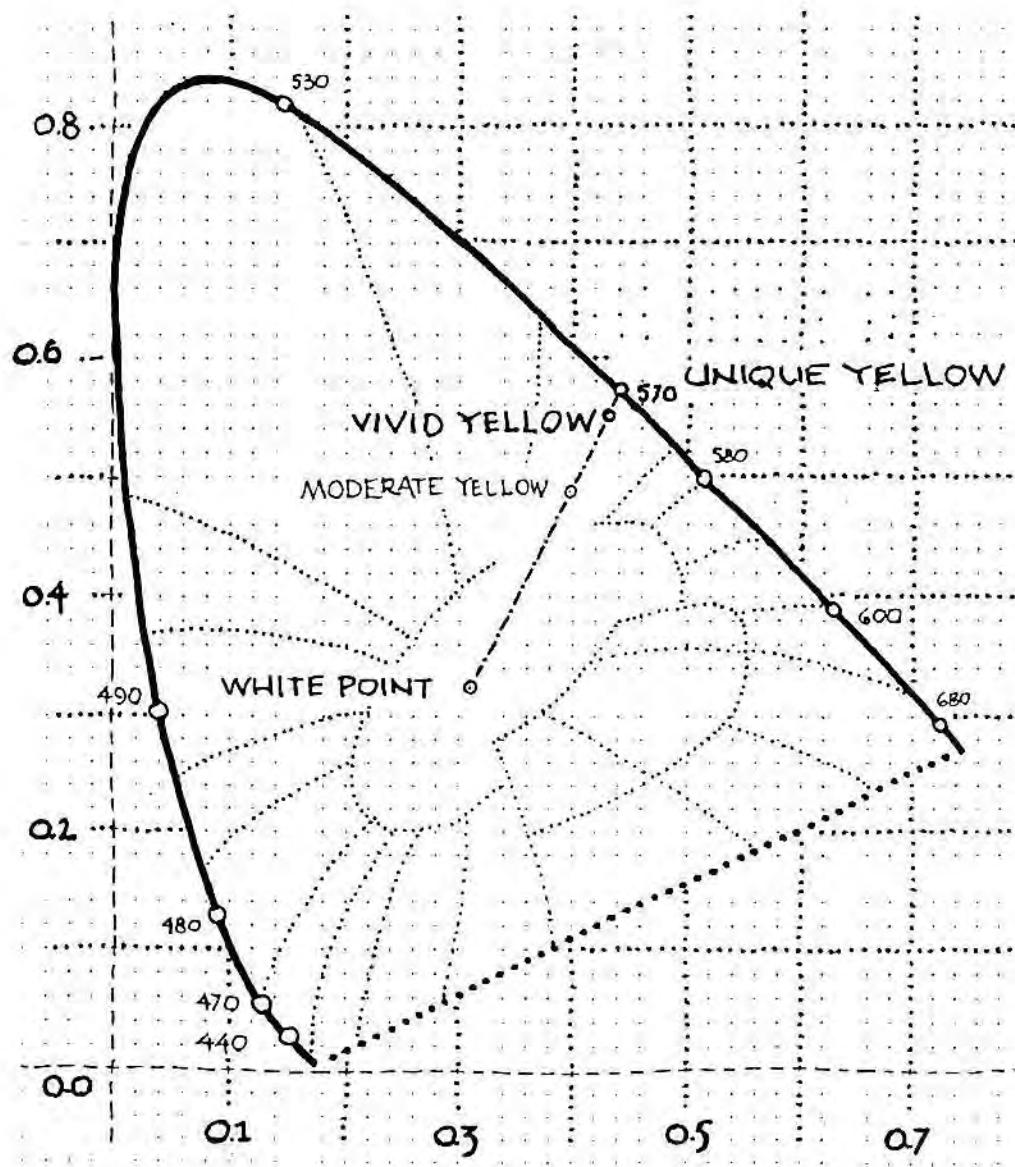


Fig.87. Conventional location of vivid yellow.

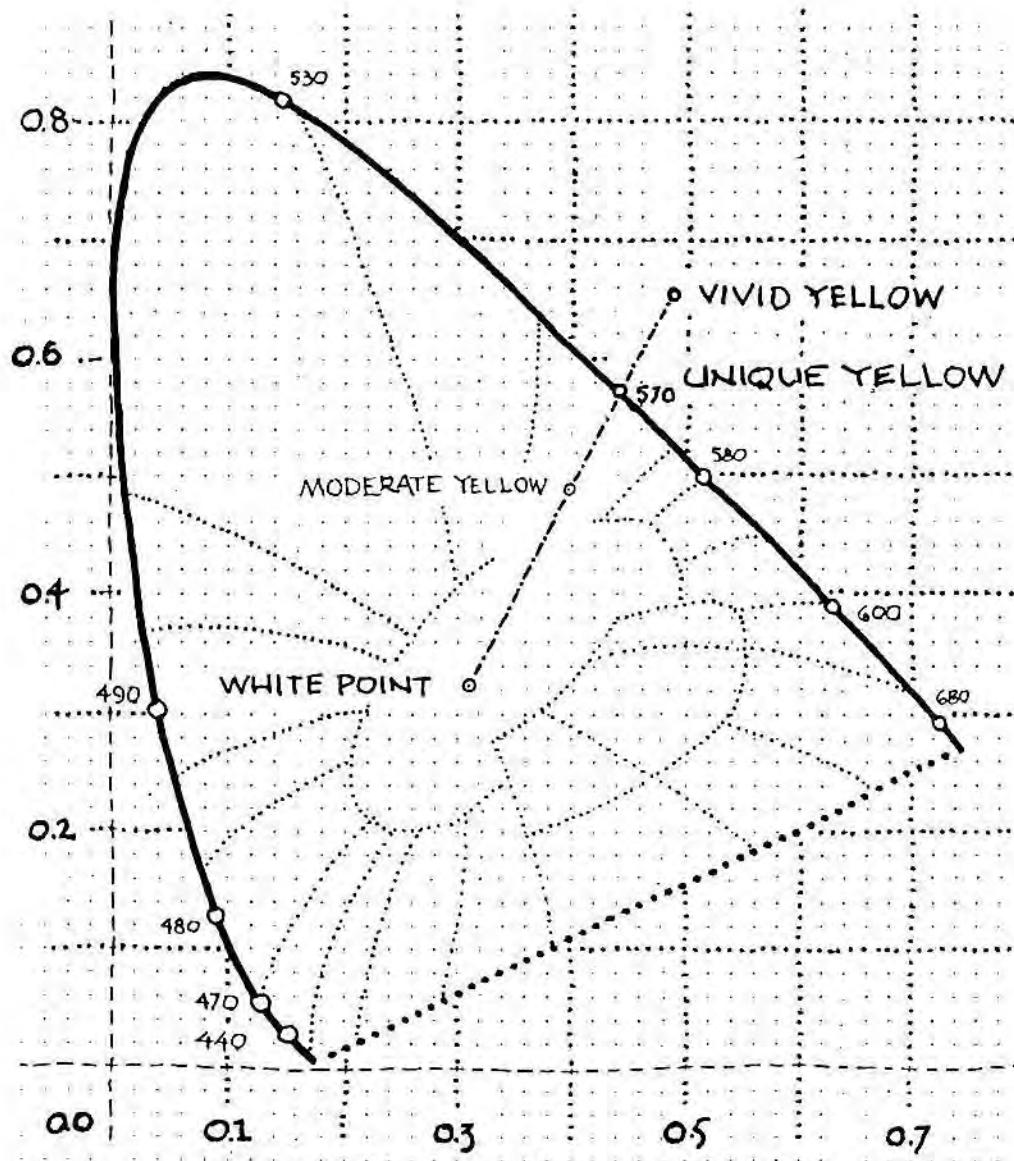


Fig.88. Suggested location of vivid yellow



Fig.89. Balthasar Neumann (1687-1753), by Maricus Friedrich Kleinert, 1727 (Manfrankisches Museum, Wurzburg).



Fig. 90. Kitzingen-Etwashausen, *Church of the Holy Cross* (1741), exterior photograph.

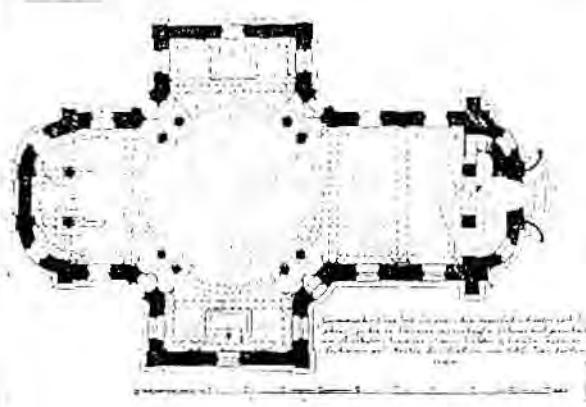
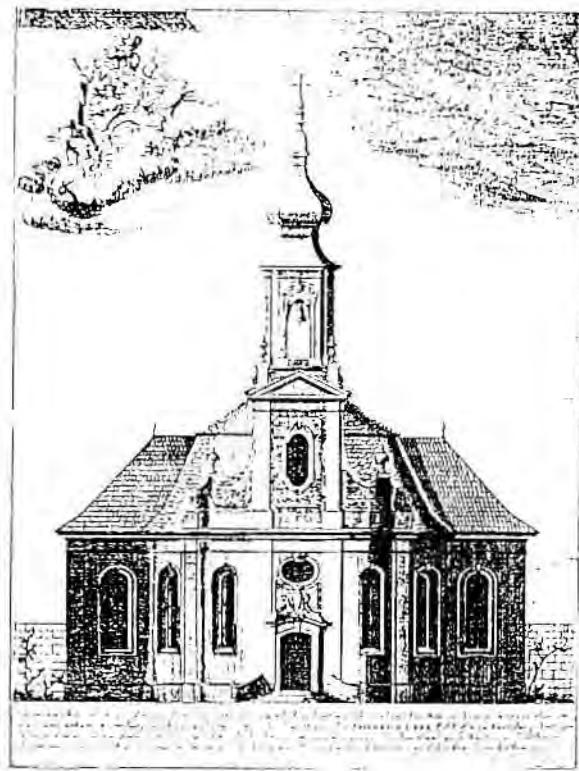


Fig. 91. Kitzingen-Etwashausen, elevation and ground plan, Kupferstiche, 1745. (Manfrankisches Museum, Wurzburg).

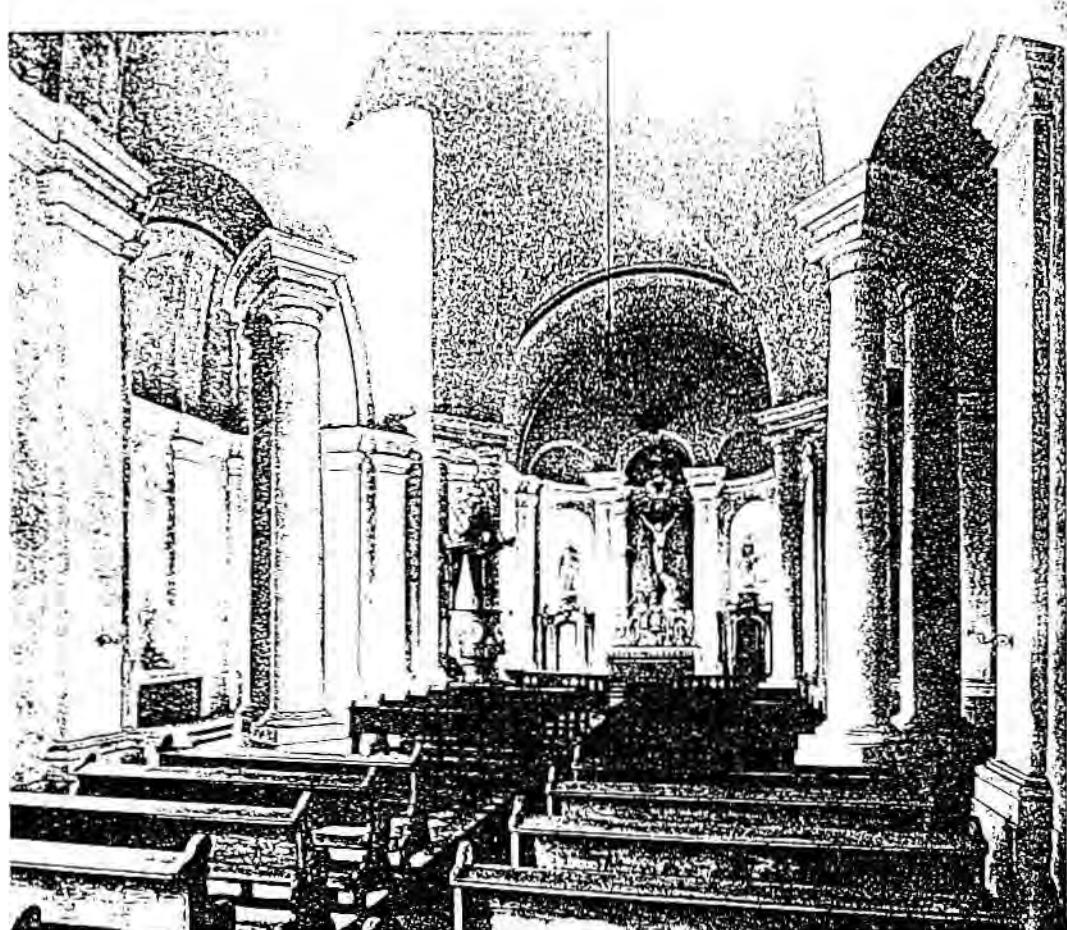


Fig. 92. Kitzingen-Etwashausen, view into the apse.

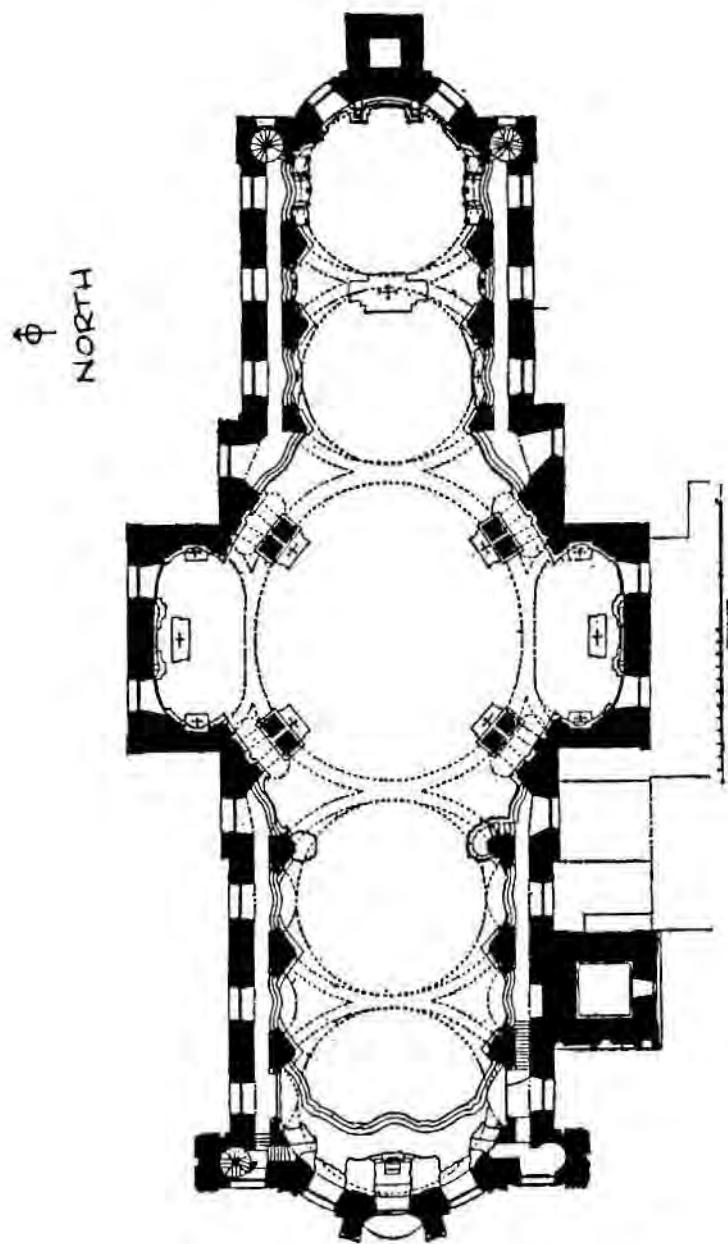


Fig. 93. Neresheim, Benedictine Abbey Church of the Holy Cross
(1748), ground plan.

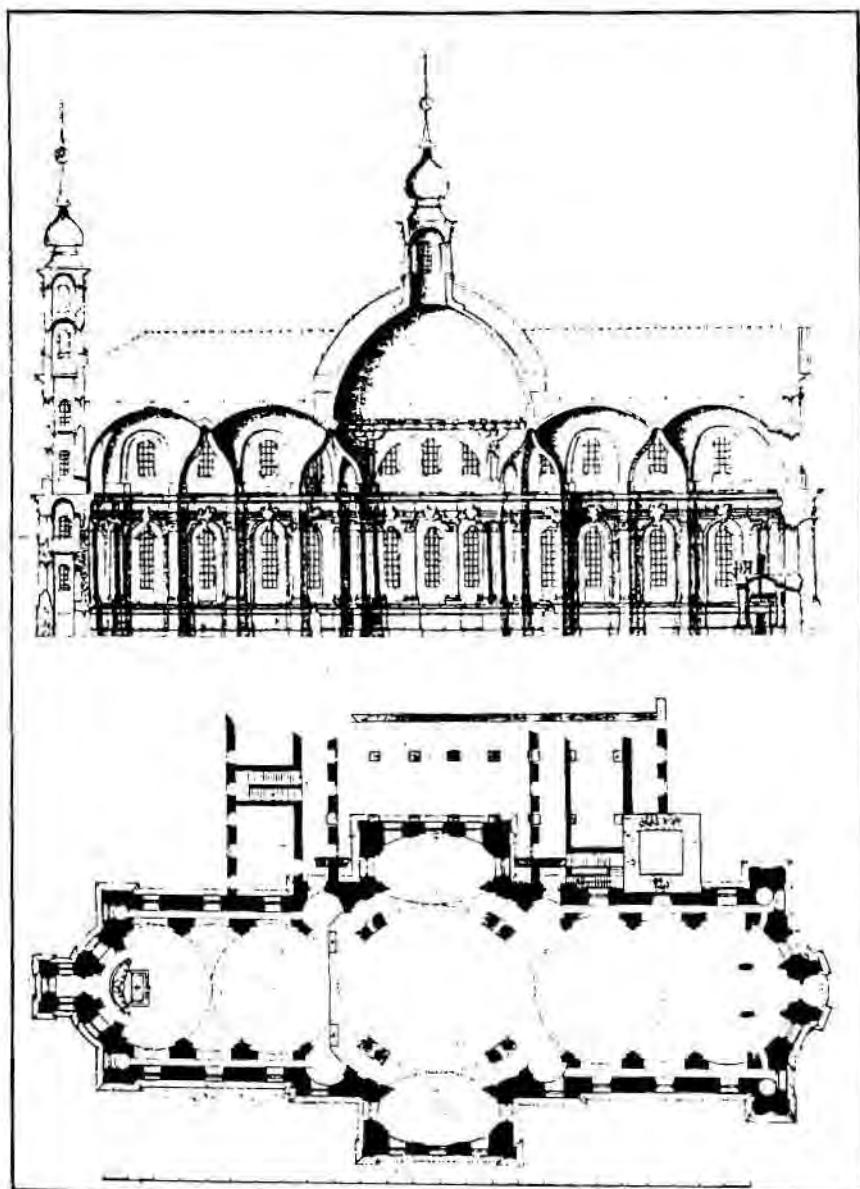


Fig. 94. Neresheim, plan and longitudinal section. Note this plan does not present the built solution to the problem of circulation. (Manfrankisches Museum, Wurzburg, S.E.120).



Fig. 95. Neresheim, west facade elevation showing Romanesque tower (true elevation makes the tower seem more pronounced than it is in perspective). Note architrave as designed by Neumann.

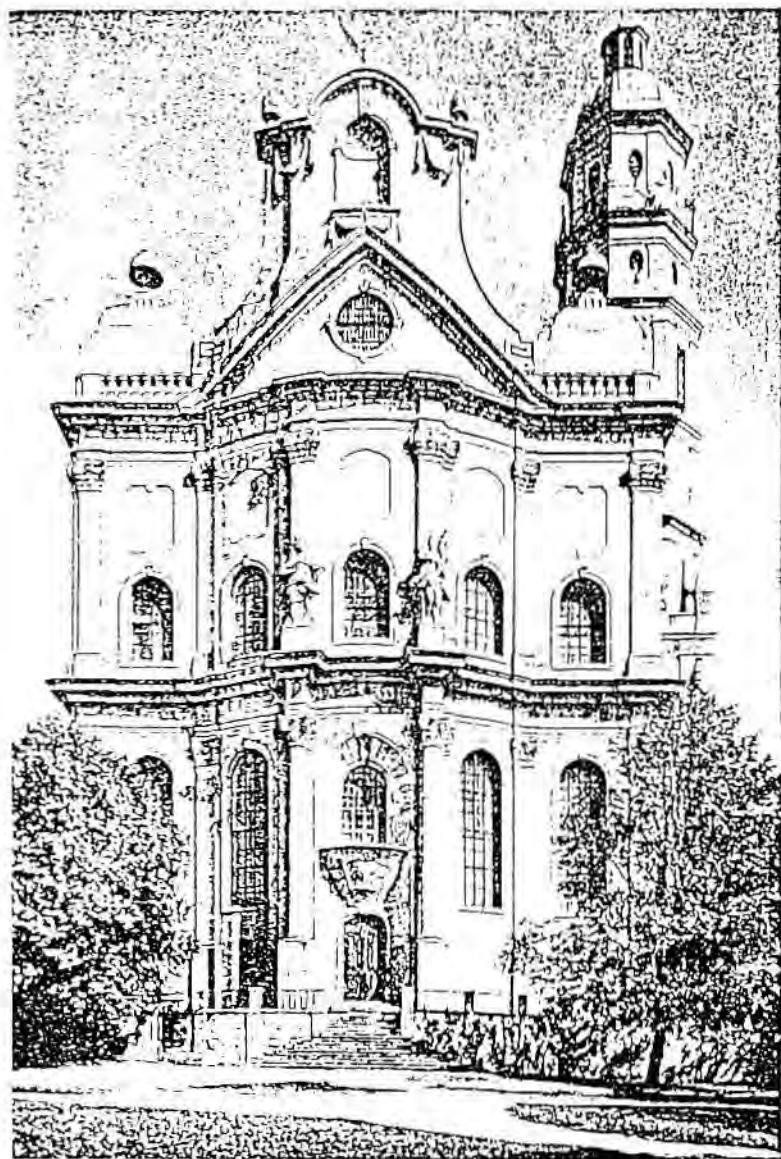


Fig. 96. Neresheim, west facade (public entrance). Note Romanesque tower and architrave as modified later.

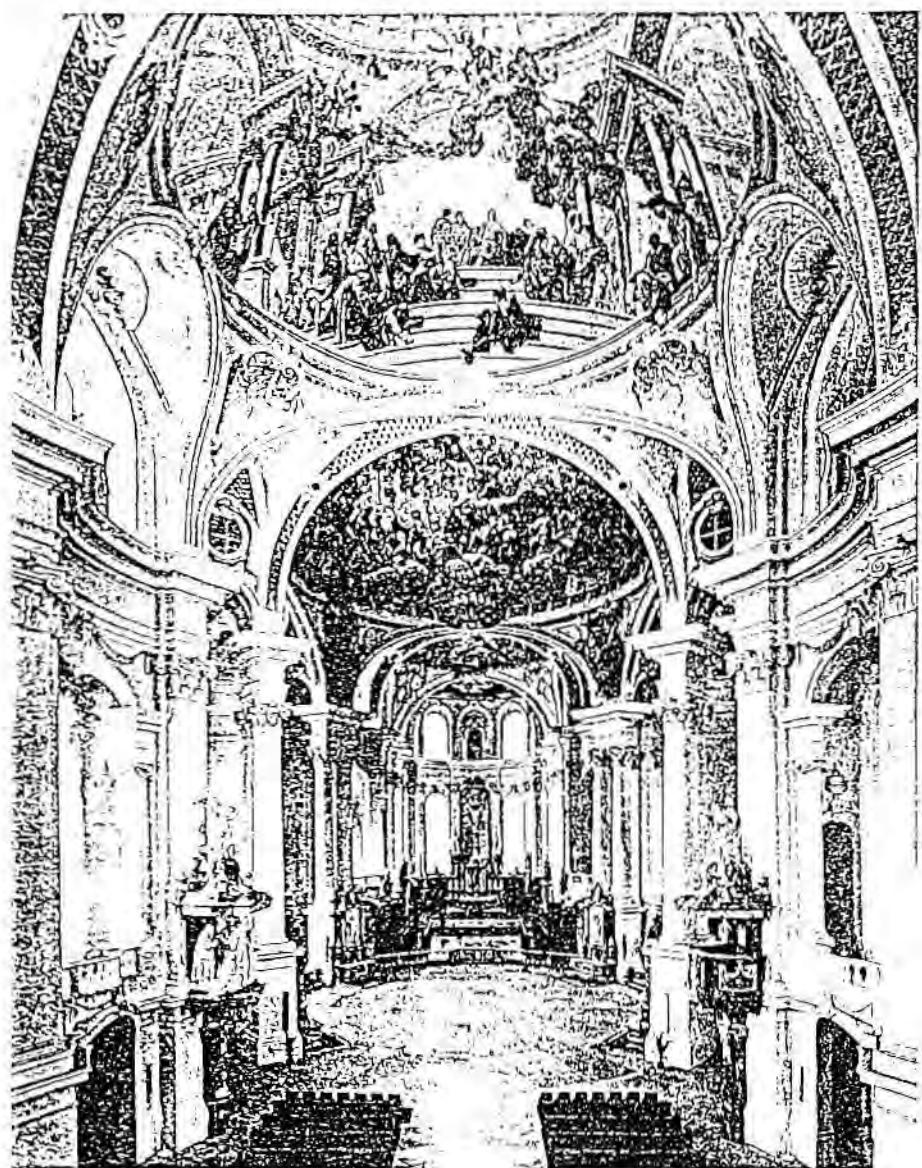


Fig. 97. Neresheim, view from the top of the balcony towards the choir. Photo taken before restoration.

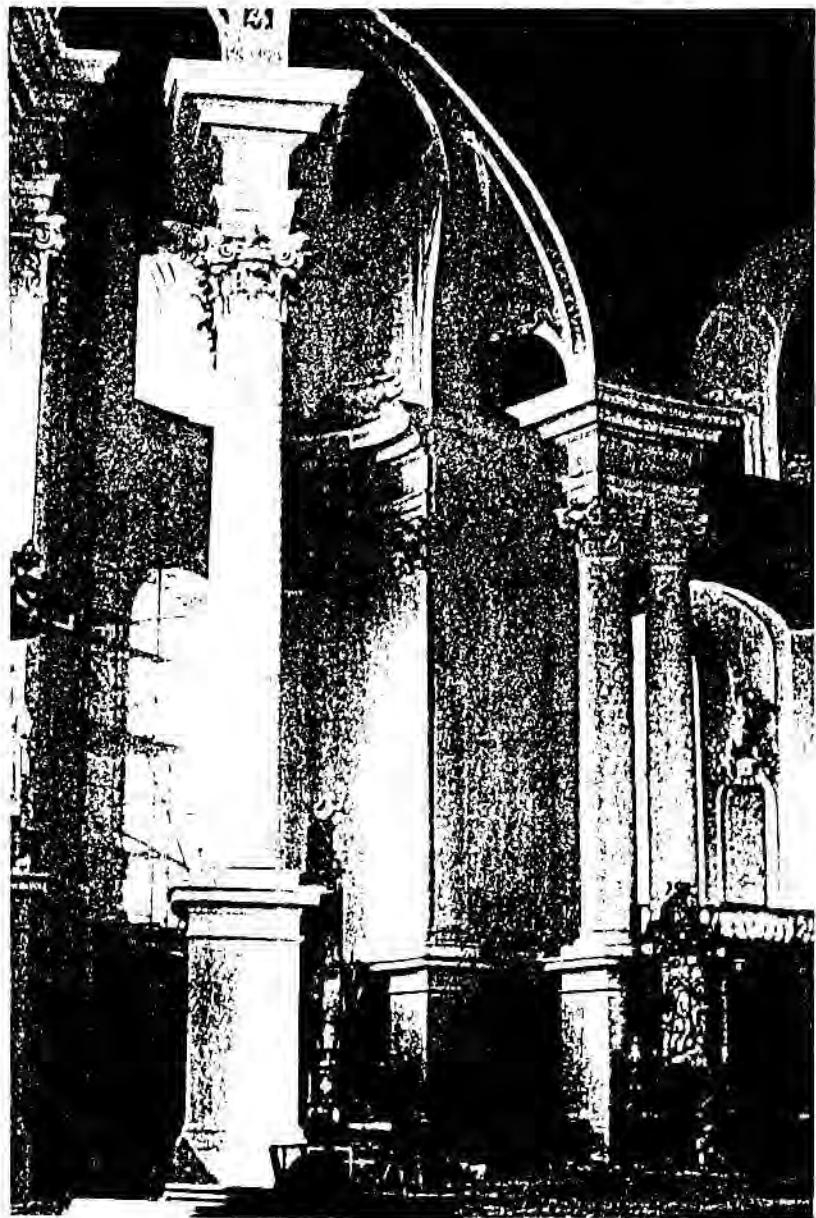


Fig. 98. Neresheim, view from the alter towards the south arm, showing two sets of detached pilasters supporting pendentives, supporting transept longitudinal ellipsoid vault.

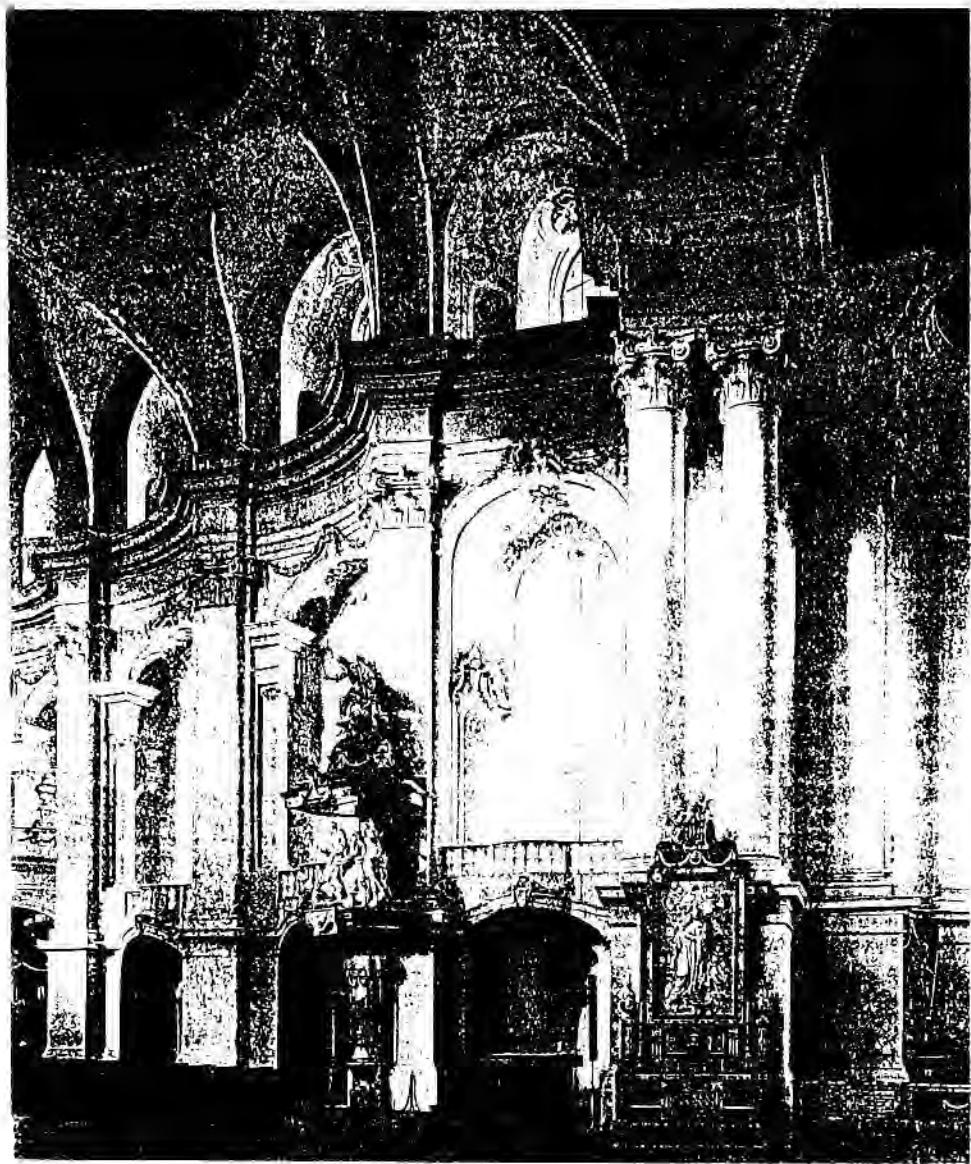


Fig.99. Neresheim, view in to north west pilaster.



Fig.100. Neresheim, nave elevation (at Romanesque tower) and torsion arches.

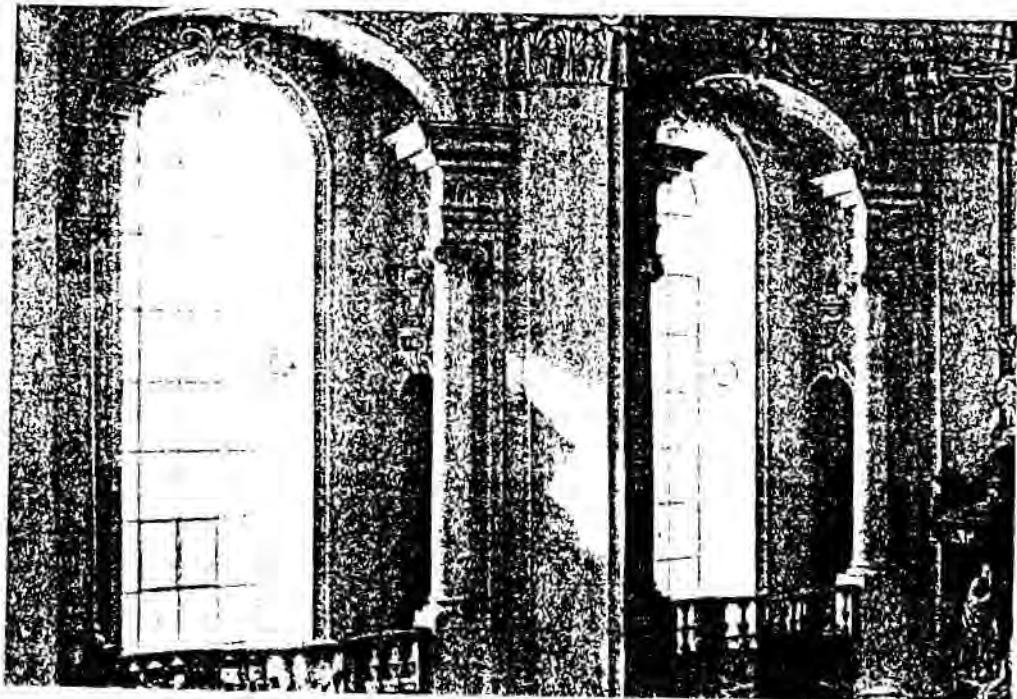


Fig.101. Neresheim, nave windows from the balcony.

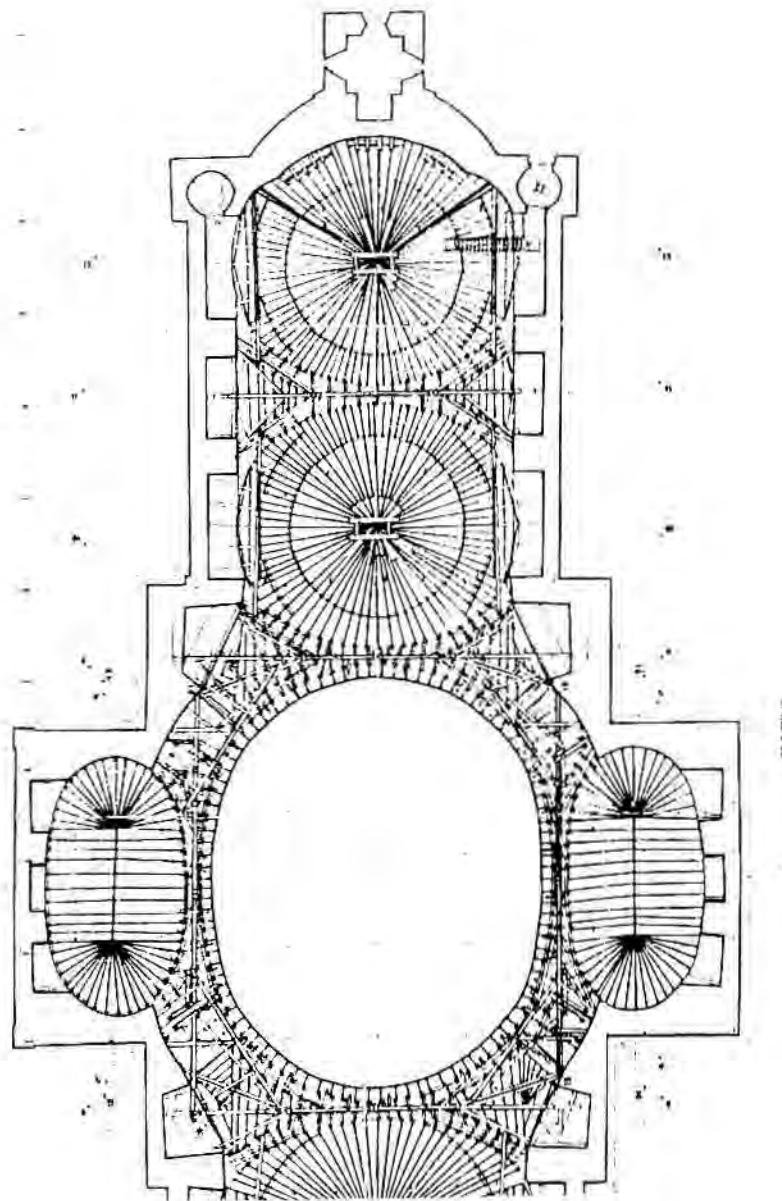


Fig. 102. Neresheim, ceiling framing plan--arms and spherical choir vaults. Ceiling framework by Franz Joseph Pfeifer, executed 1763-70.

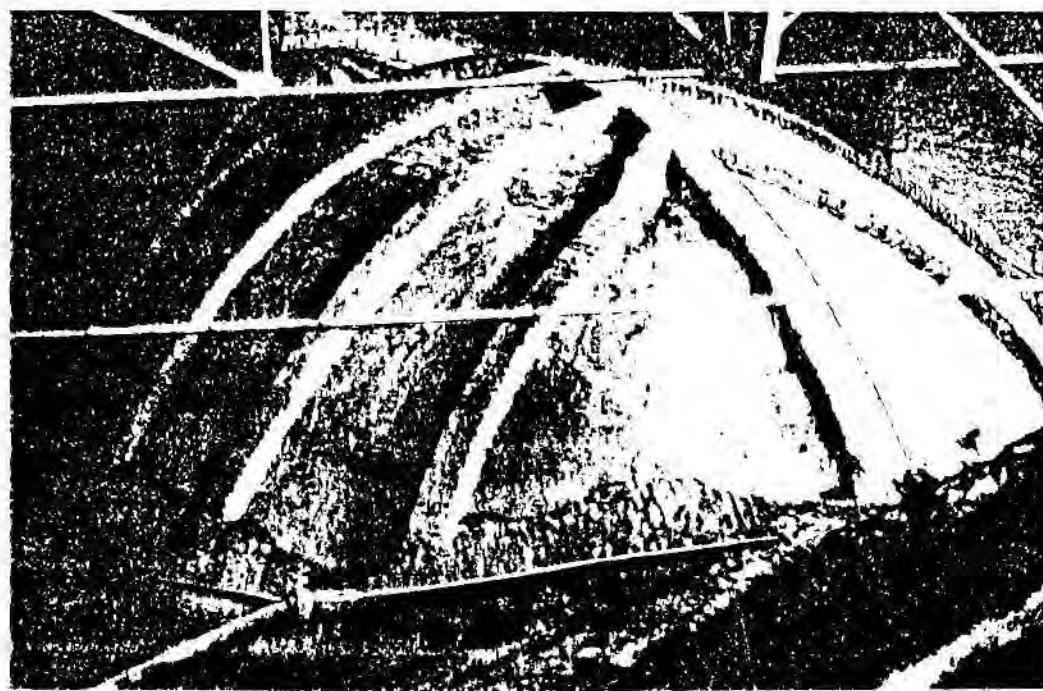


Fig.103. Wurzburg Palace Church (1732), main vault from above, mortar over brick; note rib irregularity and double coursing at bottom.

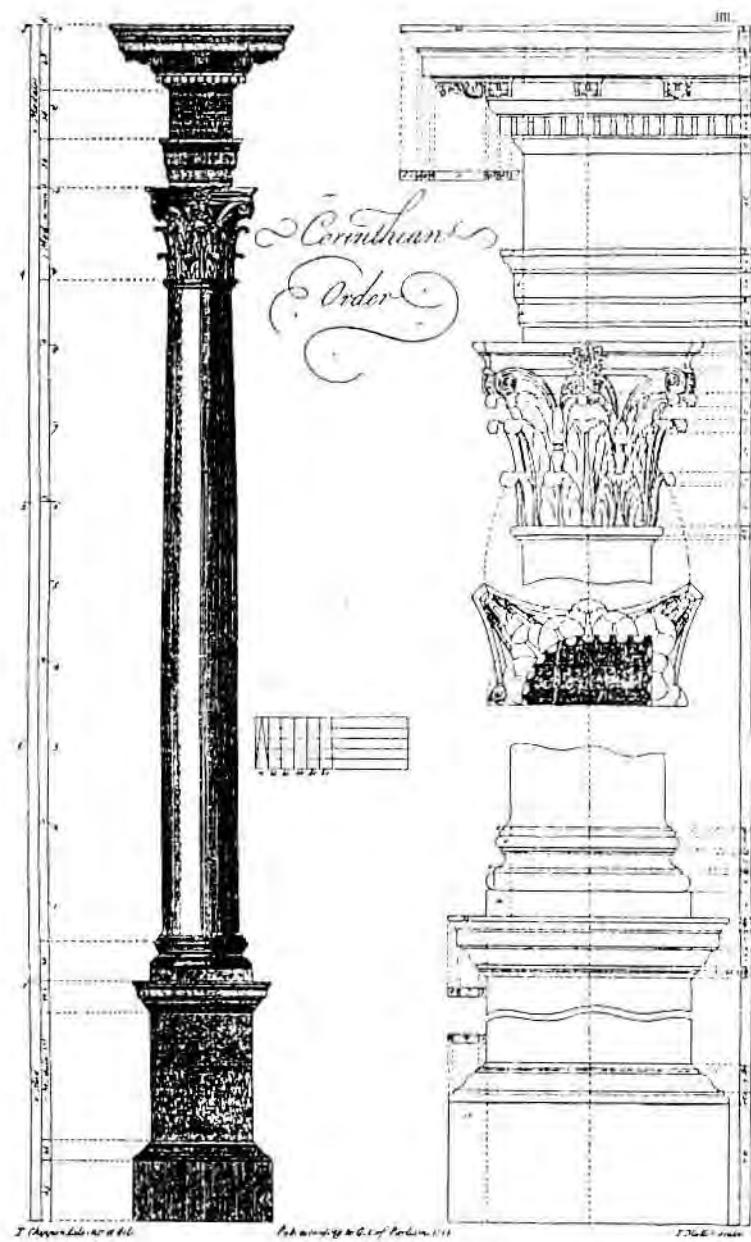


Fig.104. The Corinthian order as shown in Thomas Chippendale's furniture catalogue.

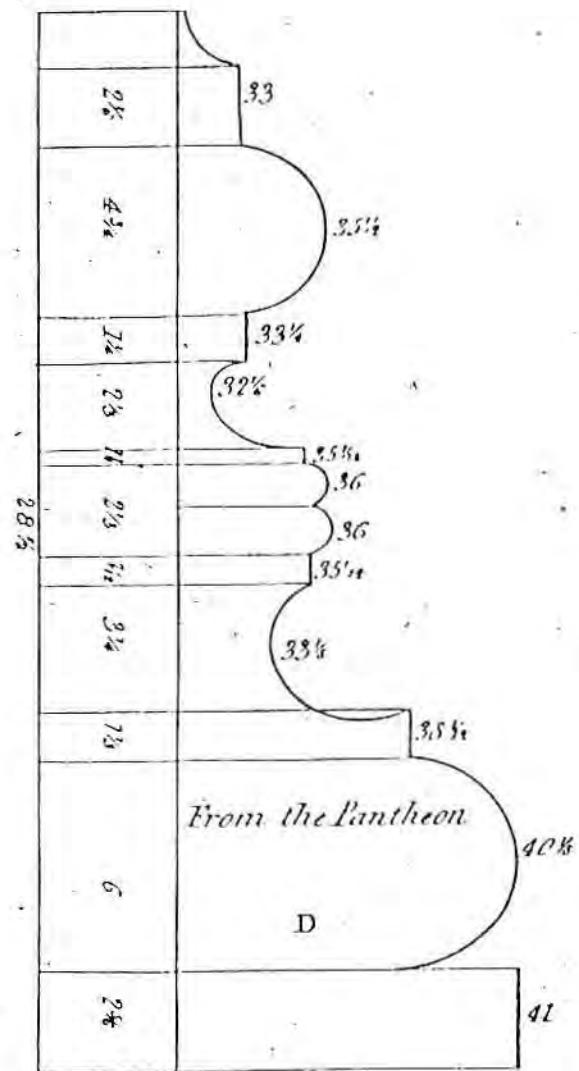


Fig.105. Column base molding from the Pantheon.

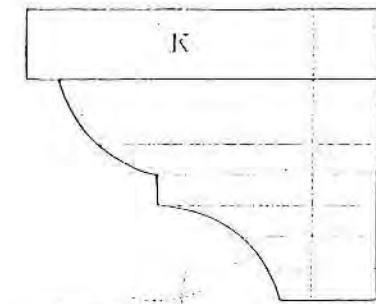
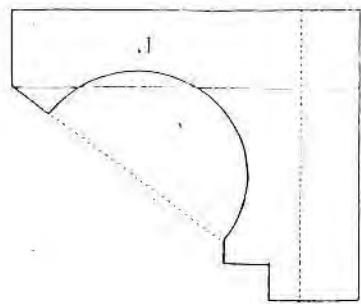
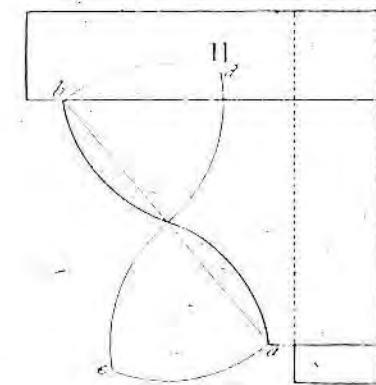
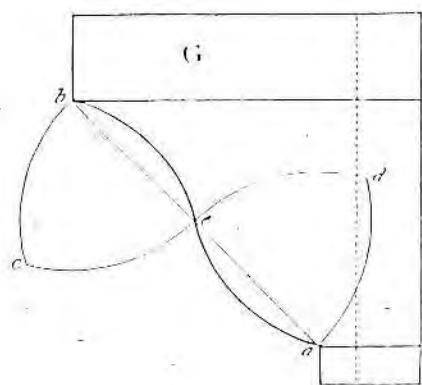
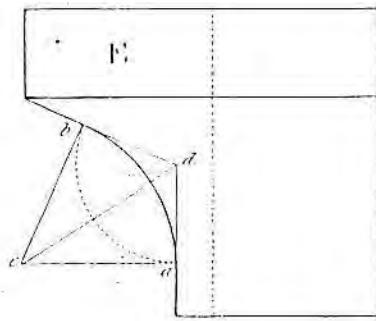
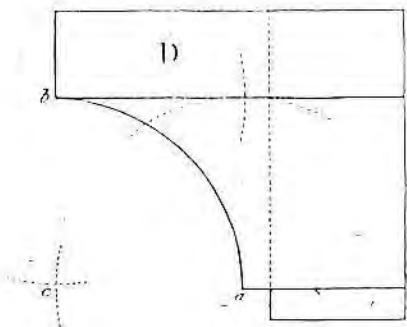


Fig.106. Geometric construction of typical profiles.

Fig. 1

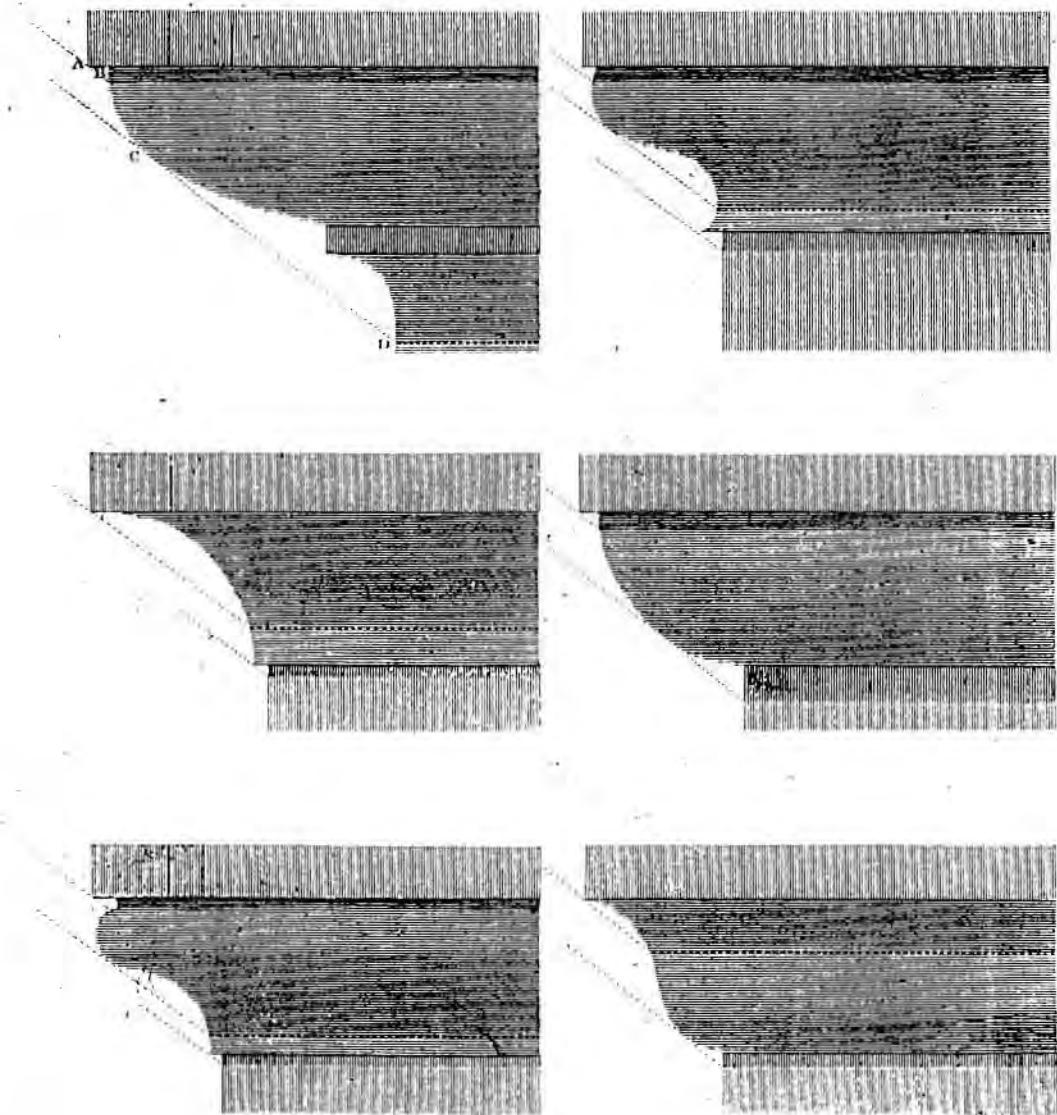


Fig. 107. Shadowed profiles.

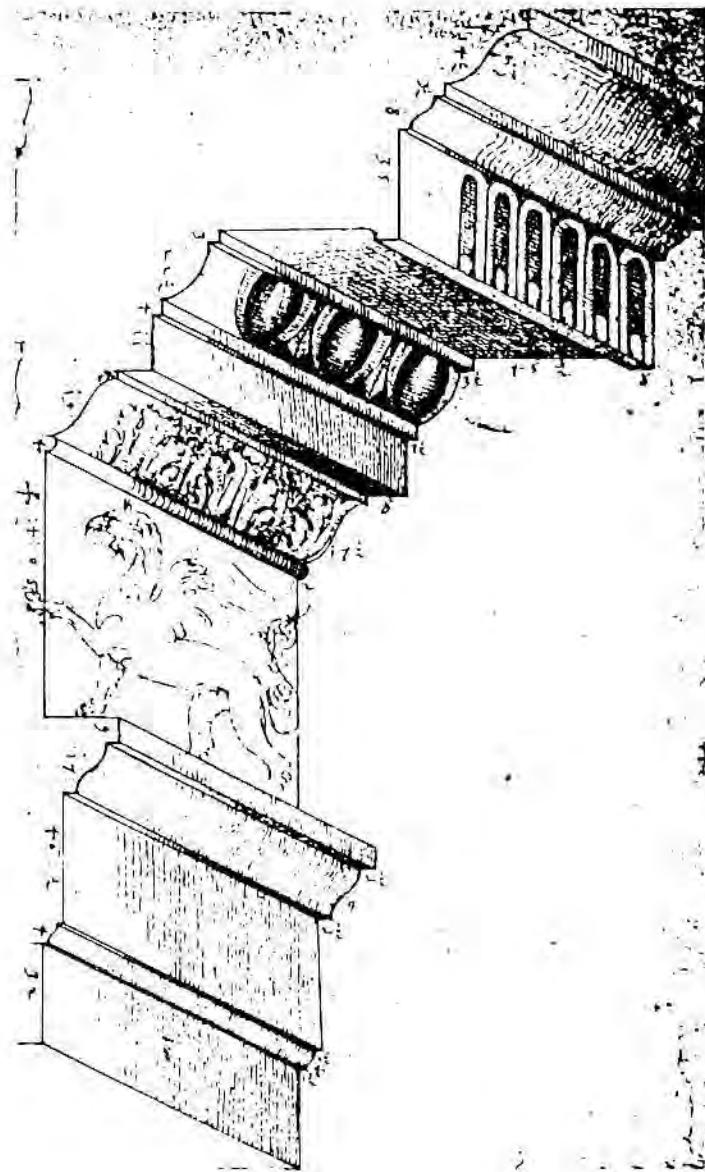


Fig.108. Built up molding by Andrea Palladio visualized as shadowed and measured elements.

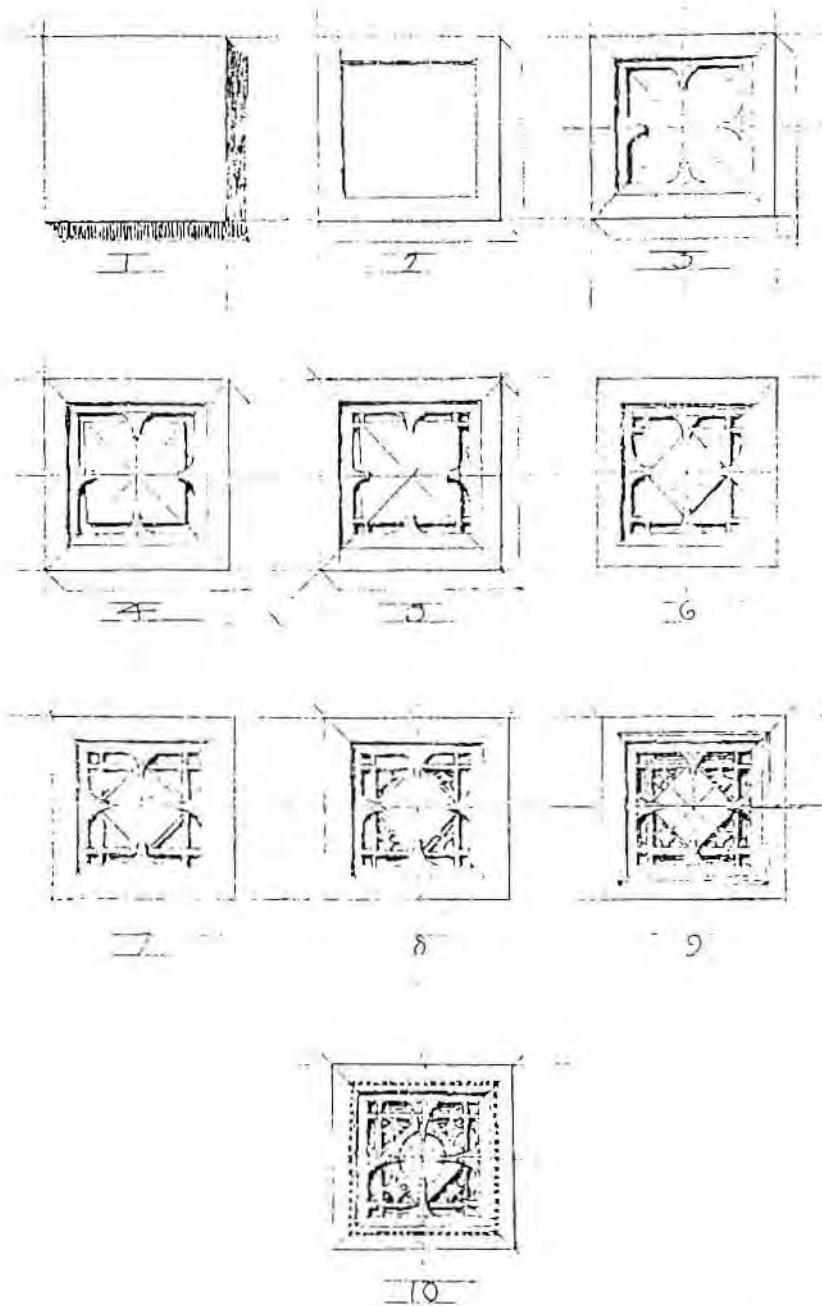


Fig.109. Louis Sullivan's drawings for ornaments are extraordinary, see Sprague (1979). Above a page from *A System of Architecture According with a Philosophy of Man's Powers*, 1924.

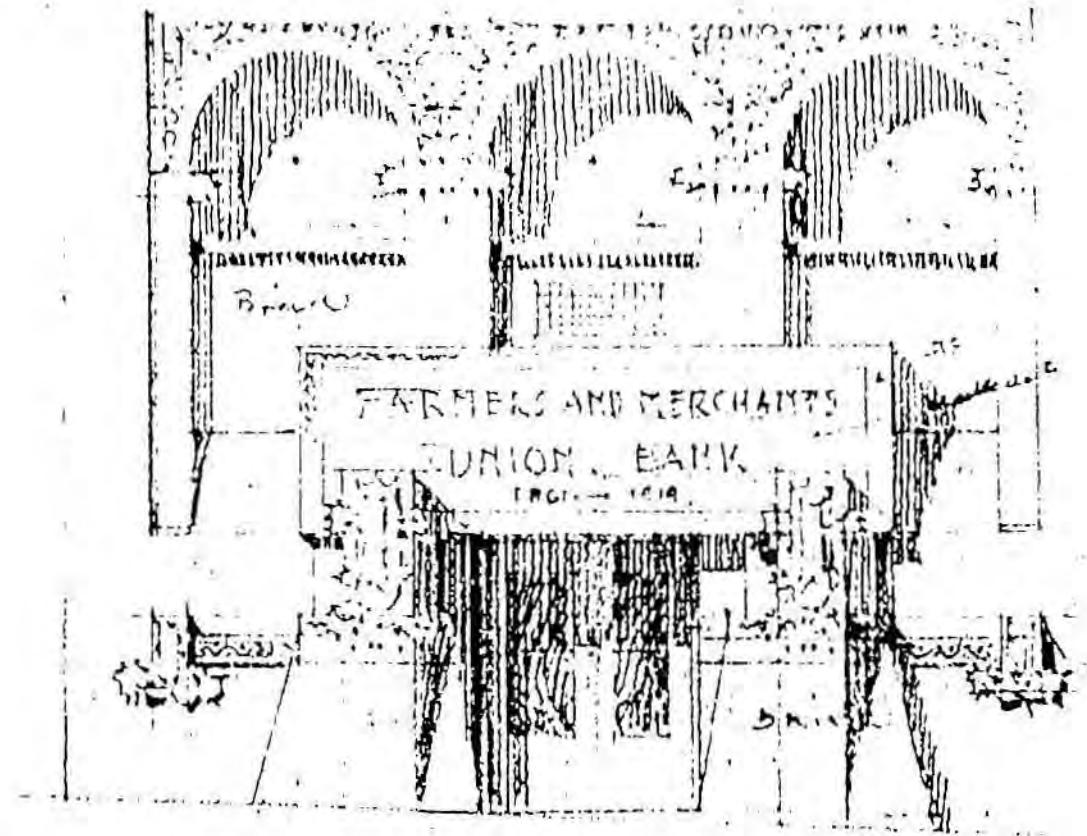


Fig. 110. Concept sketch for the entrance of Farmers' and Merchants' Union Bank Columbus Wisconsin, 1919.

